Saskatchewan
Parks, Recreation
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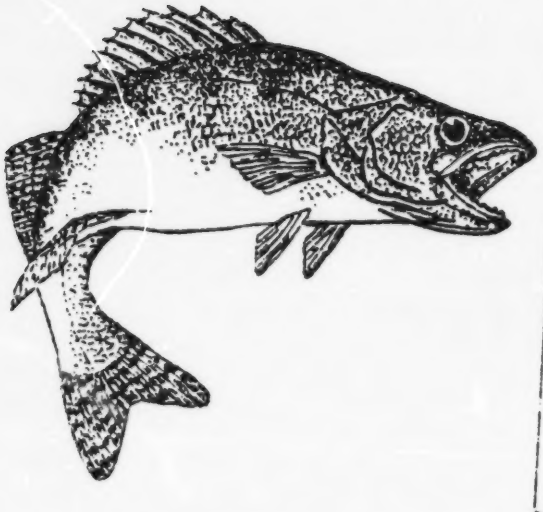
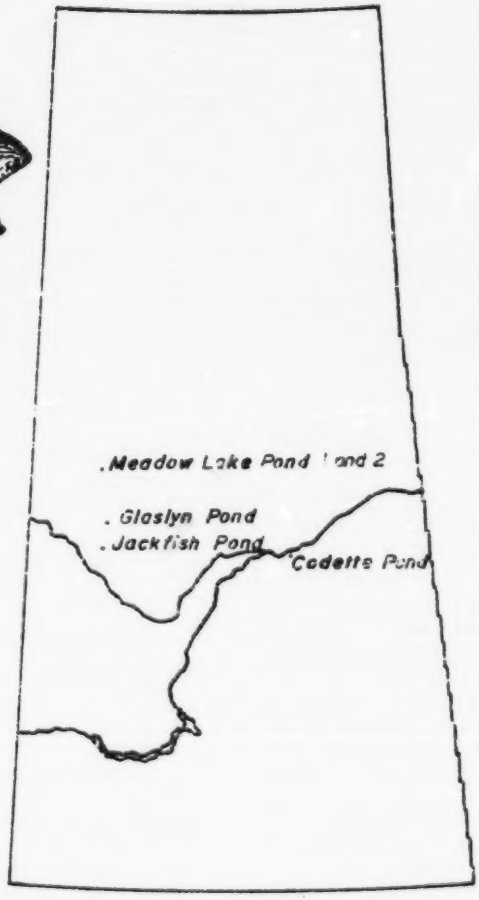
Operation and Evaluation of Several Saskatchewan Walleye Rearing Ponds, 1987

Fisheries Technical Report 87-6





Operation and Evaluation of Several Saskatchewan Walleye Rearing Ponds, 1987

Presented to

Saskatchewan Fisheries Laboratory

Department of Parks, Recreation and Culture

Saskatoon, Saskatchewan

By

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Technical Report 87-6

EXECUTIVE SUMMARY

SITUATION

Experimental management aimed at maximizing production of pond reared walleye *(Stizostedion v. vitreum)* fingerlings was conducted on five ponds in Saskatchewan. Four of the ponds (Codette, Jackfish and Meadow Lake 1 and 2) are man-made, totally drainable excavated impoundments with a combined area of 32.8 ha. One other pond (Glaslyn) is a levee impoundment with an area of 4 ha. All five ponds are totally drainable. A sixth pond - Shore Pond - was not operated but was monitored.

Pond management consisted of fertilization, manipulation of fry stocking densities and pond water levels, and fingerling harvest. Fertilizers included several applications of: alfalfa pellets (totalling 1 000 kg/ha/pond in all ponds), alfalfa hay bales (totalling 15 bales/ha in Codette and Meadow Lake Ponds) and 11-51-0 granular ammonium phosphate (totalling 25 kg/ha in Codette Pond). Stocking rates ranged from 15 400 fry/ha (Jackfish Pond) to 25 000 fry/ha (Meadow Lake Cell 1, Glaslyn Pond) to 50 000 fry/ha (Meadow Lake Cell 2, Codette Pond).

RESULTS

The estimated survival of walleye in the rearing ponds from fry to fingerling size ranged from 0% in Glaslyn Pond to 54% (27 000 fingerlings/ha) in Meadow Lake Cell 2. Meadow Lake Cell 1 essentially failed due to pike predation. No fingerlings were produced in Glaslyn Pond because of intolerable un-ionized ammonia levels associated

with low dissolved oxygen levels and alkaline pond conditions. Codette Pond achieved a survival of 37.6%. Jackfish Pond also had high un-ionized ammonia levels associated with low DO causing a partial summerkill. Estimated survival in Jackfish Pond was 24.8%. Overall survival from fry to fingerling size was 29.5%.

An estimated 335 300 fingerlings were produced in the experimental ponds during the 1987 operation. Codette Pond produced 188 239 fingerlings (18 824/ha; 45 kg/ha) which were released directly into Codette Reservoir. Meadow Lake Pond (both cells) produced 97 480 fingerlings (9 947/ha; 14.7 kg/ha) of which Cell 2 produced 97 200 fingerlings (27 000/ha; 39.9 kg/ha) and Cell 1 produced 280 fingerlings (45/ha, 0.05 kg/ha). Fingerlings produced by Meadow Lake Pond were stocked in Greig Lake. Jackfish Pond produced 49 585 fingerlings (3 814 ha; 6.6 kg/ha) which were stocked into Jackfish Lake.

Walleye fingerlings grew an average 1.0 mm/day which is similar to that obtained in other years. Over the same growing period (20-60 days after stocking) the average weight gain was 0.05 g/day, less than the 0.06 g/day expected.

The effects of fin-clipping for population estimation were found to be negligible. Enumeration and harvest methods used at Meadow Lake appeared to be stressful to the fingerlings.

Pond fertilization was effective in promoting usable zooplankton forage levels to or above a desired density of about 100 usable zooplankters/L. The response of the ponds to fertilization was highly variable. A large algal bloom developed in Codette Pond, likely a response to applications of superphosphate. Meadow Lake Pond had a small algal bloom as well.

Pond biomechanics are very complicated and some of the factors that can potentially affect walleye survival are not easily controlled. Sources of fingerling mortality this year included: high un-ionized ammonia concentrations associated with low DO levels, inadvertent introduction of predatory fish, bird predation, handling induced stress, and cannibalism in the absence of alternative food sources.

RECOMMENDATIONS

Recommendations include:

1) Increase the stocking rate to 75 000 fry/ha in Meadow Lake Pond 2 and to 50 000/ha in Codette and Meadow Lake Pond 1. All other ponds should be stocked at the same rate as in 1987.

2) Increase the amounts and frequency of fertilizer application to foster better zooplankton production.

3) Install shallow water aeration systems in Codette and Meadow Lake Ponds 1 and 2 to improve oxygen conditions, thereby reducing the risk of summerkill.

4) Fill the ponds in the fall where possible to prevent entry of small predatory fish. Any fish entering the pond will likely winterkill. Employ better screening techniques during filling to ensure that walleye fry are the only fish species stocked in the ponds in the spring.

5) Consider smaller, multi-celled pond complexes when walleye rearing ponds are excavated in the future.

6) Recommended operations for six rearing ponds in 1988 are listed in Appendix 6.

ACKNOWLEDGEMENTS

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TABLE OF CONTENTS

		Page
	EXECUTIVE SUMMARY	*i.*
	ACKNOWLEDGEMENTS	*v.*
	LIST OF FIGURES	*viii.*
	LIST OF TABLES	*ix.*
1.	INTRODUCTION	1
2.	PROCEDURES	1
	2.1 THE REARING PONDS	1
	2.2 POND FERTILIZATION	4
	2.3 STOCKING OF FRY	8
	2.4 PHYSIOCHEMICAL MONITORING	9
	2.5 BIOLOGICAL SAMPLING	10
	2.5.1 Plankton	10
	2.5.2 Fingerlings	10
	2.5.3 Pond Conditions	11
	2.6 FINGERLING ENUMERATION AND HARVESTING PROCEDURES	11
3.	RESULTS	13
	3.1 LIMNOLOGICAL OBSERVATIONS	13
	3.1.1 Water Temperature, Dissolved Oxygen, pH and Un-ionized Ammonia	13
	3.1.2 Water Quality	18
	3.1.3 Net-Plankton Standing Crop	19
	3.2 FINGERLING PREY SELECTIVITY	23
	3.3 FINGERLING GROWTH	28
	3.4 SURVIVAL AND PRODUCTION	31

	Page
3.5 HARVEST AND RESTOCKING	31
3.6 FINGERLING PREDATION	31
4. DISCUSSION	34
4.1 POND BIOMECHANICS	34
4.2 FINGERLING GROWTH AND PRODUCTION	37
4.3 SOURCES OF FINGERLING MORTALITY	39
4.3.1 Water Quality	39
4.3.2 Predation	41
4.3.3 Post Stocking Mortality	43
5. SUMMARY/CONCLUSIONS	43
6. RECOMMENDATIONS	44
6.1 POND FERTILIZATION	45
6.2 STOCKING FRY	46
6.3 AERATION	46
6.4 POND ALTERATION AND DESIGN	46
6.5 MONITORING PROCEDURES	47
6.6 FINGERLING HARVEST PROCEDURES	47
6.7 POND WATER LEVELS	48
7. LITERATURE CITED	50
8. APPENDICES	53

LIST OF FIGURES

		Page
1.	Bathymetric map of Codette Pond, 1987.	3
2.	Bathymetric map of Jackfish Pond, 1987.	5
3.	Bathymetric map of Meadow Lake Pond, 1987.	6
4.	Temperature and oxygen profiles for Codette and Jackfish Ponds.	14
5.	Temperature and oxygen profiles for Meadow Lake ponds 1 and 2.	15
6.	Temperature and Oxygen profiles for Glaslyn and Shore Ponds.	16
7.	Changes in zooplankton standing crop in Codette and Jackfish Ponds.	20
8.	Changes in zooplankton standing crop in Meadow Lake Pond.	21
9.	Changes in zooplankton standing crop in Glaslyn and Shore Ponds.	22
10.	Changes in frequency of occurrence of food items in walleye fingerling diet in Codette Pond.	24
11.	Changes in frequency of occurrence of food items in walleye fingerling diet in Jackfish Pond.	25
12.	Changes in frequency of occurrence of food items in walleye fingerling diet in Meadow Lake Cell 1.	26
13.	Changes in frequency of occurrence of food items in walleye fingerling diet in Meadow Lake Cell 2.	27
14.	Growth curve of walleye fingerlings.	29
15.	Weight curve of walleye fingerlings.	30

LIST OF TABLES

		Page
Table 1	Location and morphometric characteristics of the rearing ponds at FSL.	2
Table 2	Total pond fertilization rates.	7
Table 3	Surface water temperature, dissolved oxygen, pH and un-ionized ammonia (NH3) in rearing ponds: May - June, 1987.	17
Table 4	Percent survival and estimated population density and yield of walleye fingerlings, 1987.	32

1. INTRODUCTION

This report evaluates the experimental management of five Saskatchewan walleye rearing ponds operated in 1987. Background for this Fish Enhancement Project is detailed in Arsenault (1987) and Liaw (1987, 1984).

In 1987, the project emphasis was placed on Codette, Jackfish, Meadow Lake and Glaslyn rearing ponds. Pond fertilization, water level manipulation, stocking density manipulation, timing of stocking, and harvesting of fingerlings (timed to coincide with low forage levels), were the principal management techniques used to maximize fingerling production. Shore pond, at Delaronde Lake, was not stocked or fertilized this year, but monitoring was carried out as time permitted.

2. PROCEDURES

2.1 THE REARING PONDS

Codette, and the Meadow Lake Ponds are man-made totally drainable excavated impoundments. Glaslyn and Jackfish Ponds are also drainable but utilize mainly dike work along a slope to impound water. Shore Pond is a natural, partially drainable pond. Table 1 shows the morphometric characteristics of the ponds.

Codette Pond (Fig. 1) is a cooperative fish enhancement project between the Saskatchewan Power Corporation, and the Department of Parks, Recreation and Culture, Fisheries Branch. The pond is situated on agricultural land bordered by aspen forest, adjacent to the Saskatchewan River. Codette Reservoir is utilized as the water source.

Table 1. Location and morphometric characteristics of the rearing ponds at FSL.

Pond	Location	Area (ha)	Volume ($10^3 m^3$)	Depth (m) Mean	Depth (m) Maximum
Codette	20-49-17-W2	10.0	200.0	2.0	2.2
Jackfish	9-48-17-W3	13.0	176.0	1.4	2.3
Meadow Lake - Cell 1	25-59-17-W3	6.2	117.9	1.9	2.5
Meadow Lake - Cell 2	25-59-17-W3	3.6	70.3	1.95	2.5
Glaslyn	10-51-16-W3	4.0	-	-	1.7
Shore	23-57-7-W3	19.0	254.0	1.3	2.0

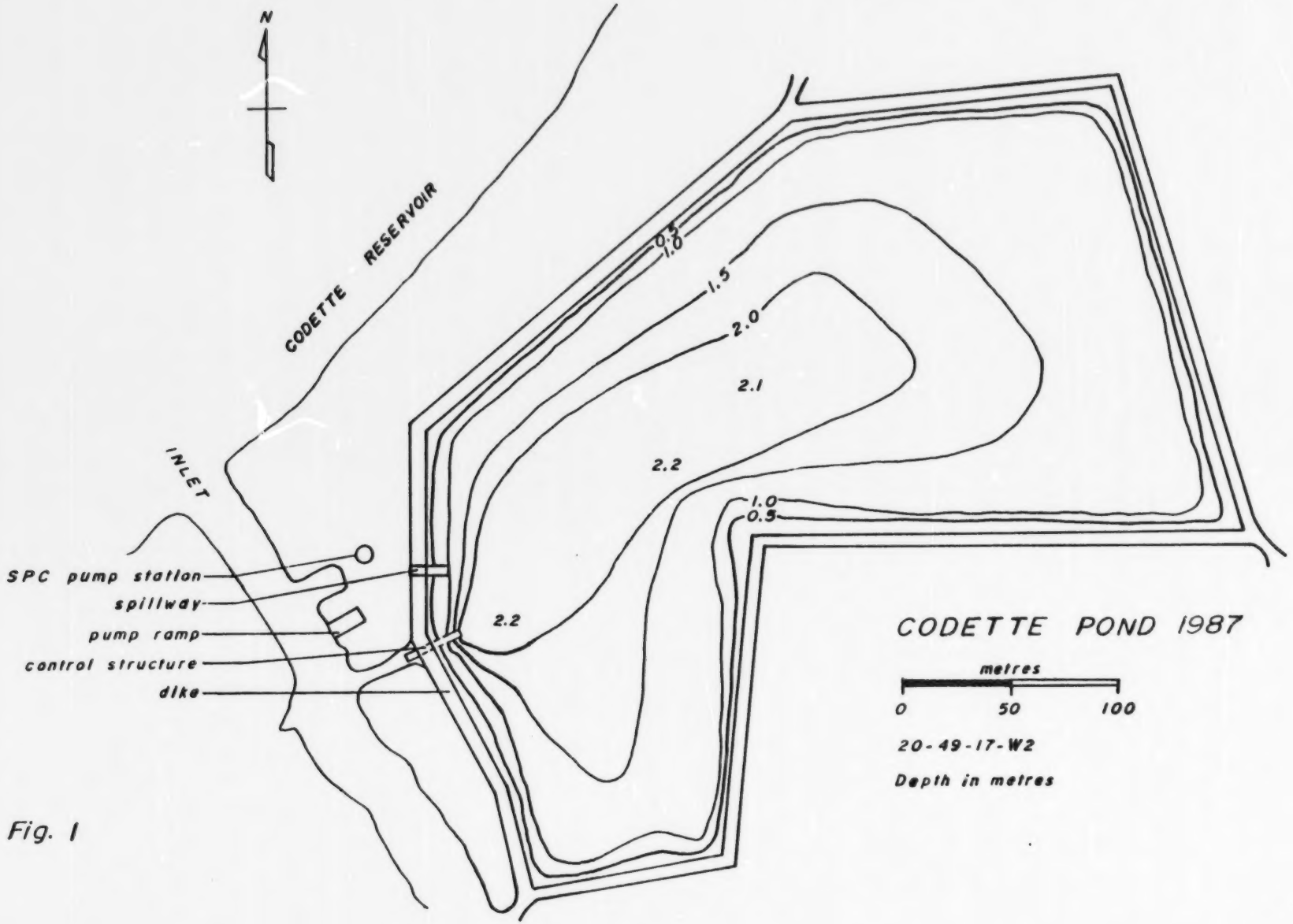

N
CODETTE RESERVOIR
INLET
SPC pump station
spillway
pump ramp
control structure
dike
0.5
1.0
1.5
2.0
2.1
2.2
2.2
1.0
0.5
CODETTE POND 1987
metres
0
50
100
20-49-17-W2
Depth in metres

Fig. 1

Jackfish Pond (Fig. 2) is a joint venture between the Battlefords Wildlife Federation and Fisheries Branch. It is situated on agricultural/pastureland adjacent to the north end of Jackfish Lake. Jackfish Lake is utilized as the water source.

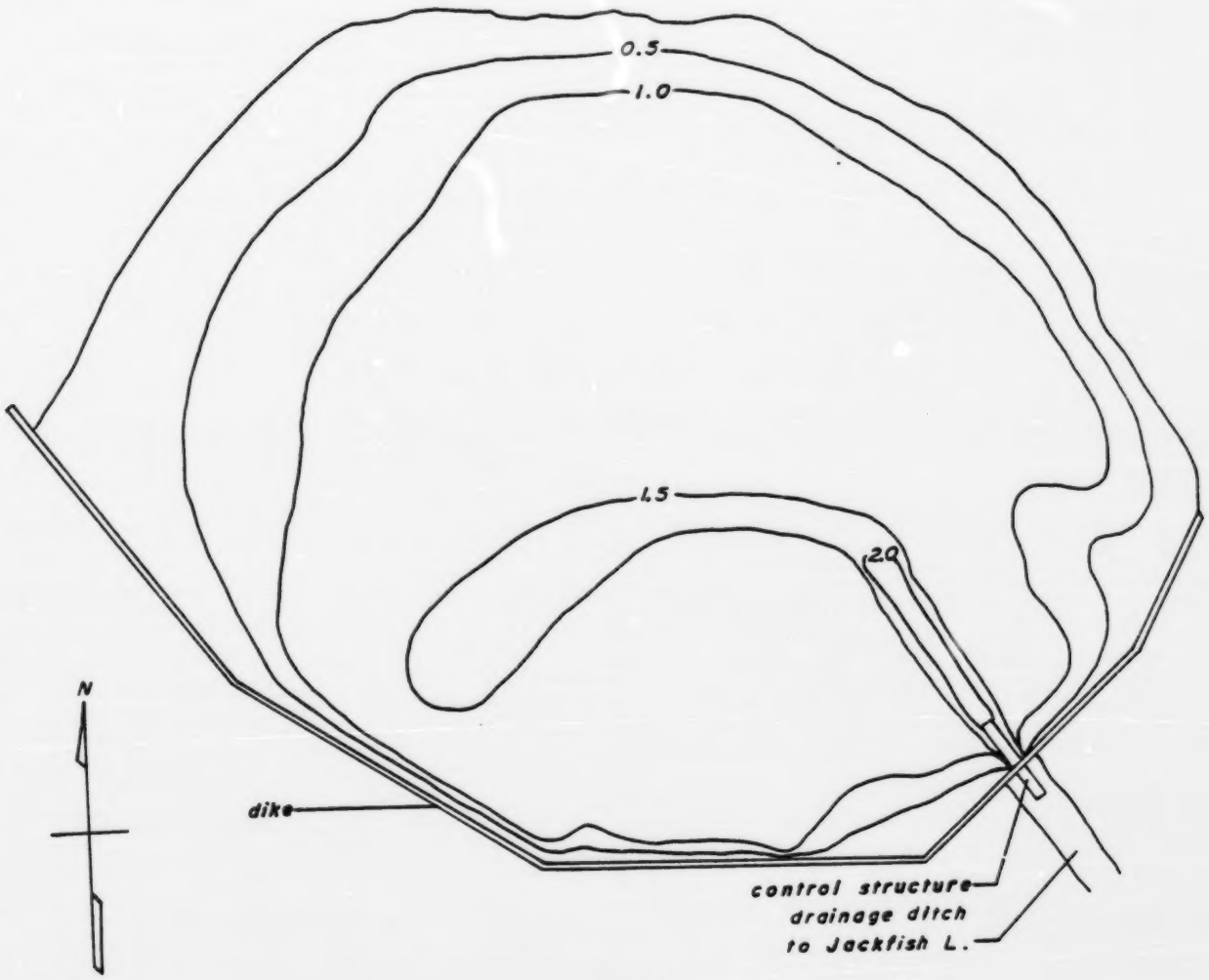
The two Meadow Lake Ponds (Fig. 3) were built and managed by Fisheries Branch. They are located at the town of Meadow Lake adjacent to slough and pastureland. They share a common dike with the town water treatment ponds at the north end. The ponds are totally drainable cells and are separated by a common dike. The Meadow River is utilized as the water source. The 1987 pond operation was intended to produce fingerlings for Greig Lake.

Glaslyn Pond (no map available) is also a cooperative fish enhancement project between the Turtle River Wildlife Federation and Fisheries Branch. It is situated on pastureland and utilizes Curry Lake as a water source. Its purpose is to provide fingerlings to stock lakes in its vicinity.

Shore Pond is a natural water body managed by Fisheries Branch. It is situated in a mixed aspen-spruce woodland adjacent to Delaronde Lake and is separated from the lake by a narrow seawall. A muskeg feeder stream is located at its south end but Delaronde Lake is utilized as the principal water source when manipulating water levels.

2.2 POND FERTILIZATION

Table 2 presents the fertilization rates used in 1987. Square alfalfa hay bales were spread on the respective ponds in March, prior to spring thaw. Alfalfa pellets were added at the



JACKFISH POND 1987

metres

0 50 100

9-48-17-W3

Depth in metres

Fig. 2

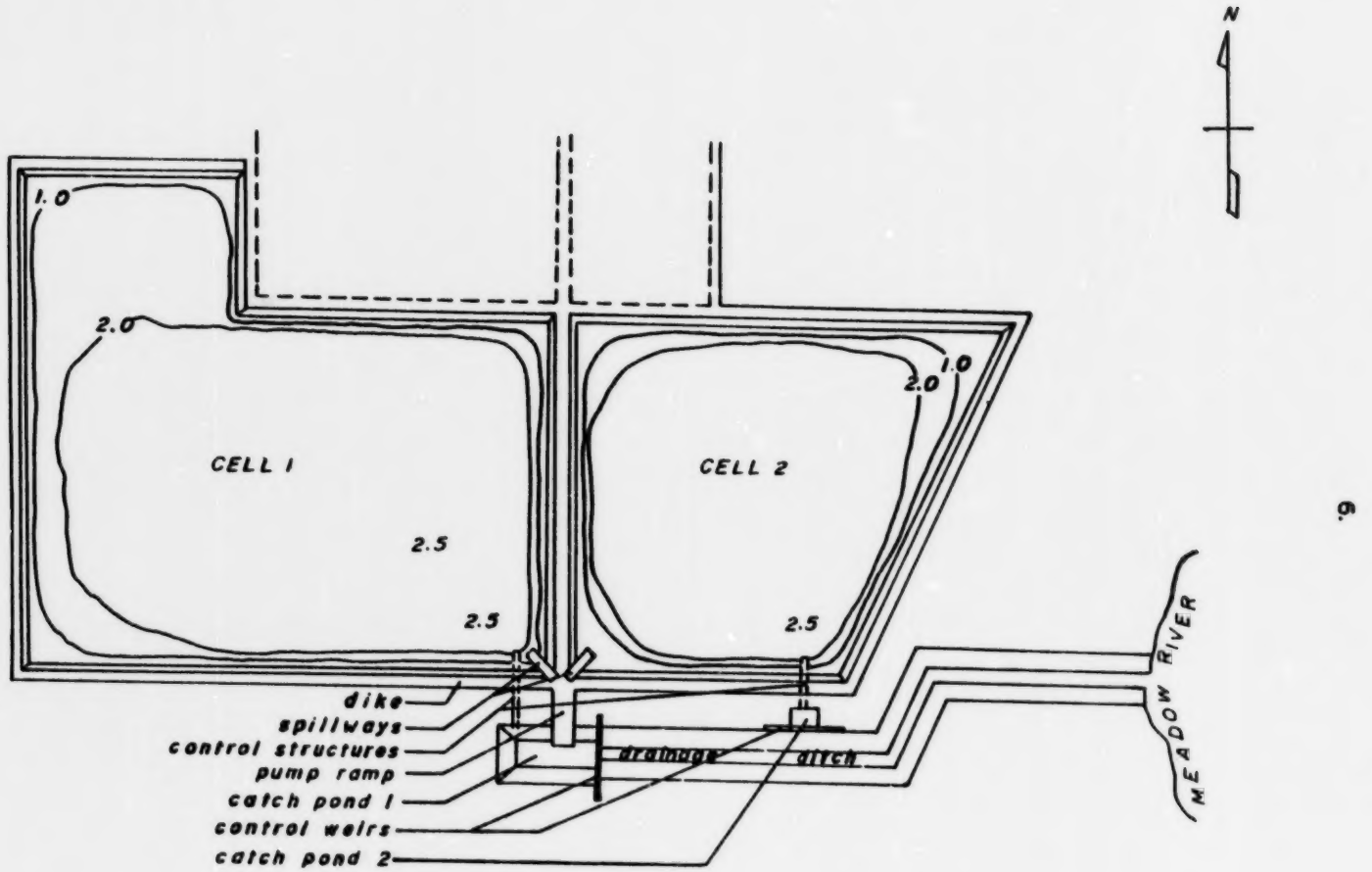

N
1.0
2.0
CELL 1
2.5
2.5
1.0
2.0
CELL 2
2.5
MEADOW RIVER
dike
spillways
control structures
pump ramp
catch pond 1
control weirs
catch pond 2
drainage ditch
MEADOW LAKE POND 1987
metres
0 50 100
25-59-17-W3
Depth in metres

Fig. 3

Table 2. Total pond fertilization rates.

Pond	Square Alfalfa Hay Bales (no/ha)	Alfalfa Pellets (kg/ha)	Superphosphate (kg/ha)
Codette	15	1000	25
Jackfish	-	1000	-
Meadow Lake 1	15	1000	-
Meadow Lake 2	15	1000	-
Glaslyn	-	1000	-
Shore	-	-	-

rate of 400 kg/ha, 10-12 days before stocking fry, and 200 kg/ha in each of three applications within a month after stocking. In addition to the pellets, Codette received 3 applications of 11-51-0 granular ammonium phosphate after stocking (two applications were at 10 kg/ha and one at 5 kg/ha). Dates of fertilizer applications are presented in Fig. 7-9.

2.3 STOCKING OF FRY

Packing, shipping and stocking procedures were those followed by the Provincial Fish Culture Station at Fort Qu'Appelle. Fry enumeration was done by the von Bayer method (volumetric estimation of eyed eggs) as described by Nielsen and Johnson (1983) for Codette, Meadow Lake and Glaslyn Ponds, and by visual estimation for Jackfish Pond. Enumeration was done by hatchery staff.

Fry were transported in 23 L polyethylene cubitainers which were filled to about two-thirds with oxygen saturated water. The remaining one-third of the container was filled with oxygen and securely closed. The cubitainers were loaded into a vehicle and covered with some ice (to slow warming) and a tarpaulin to keep the fry in a dark, cool condition while in transport. Upon arrival at the pond site, water temperatures of both the containers and the pond were checked. The fry were tempered in the closed containers. The containers were rotated frequently to prevent fry from crowding into the corners and suffocating. About 25 000 to 50 000 fry (2-5 days old) were transported in each container. All ponds were stocked with fry raised at the Fish Culture Station. Stocking rates were as follows:

Pond	Date Stocked	No. Stocked	Stocking Rate (No/ha)
Codette	25 May 87	500 000	50 000
Jackfish	25 May 87	200 000*	15 400
Meadow Lake 1	27 May 87	155 000	25 000
Meadow Lake 2	27 May 87	180 000	50 000
Glaslyn	21 May 87	100 000	25 000
Shore	not stocked		

*The initial stocking of 325 000 fry in Jackfish pond on 21 May 1987 was unsuccessful; 200 000 fry were restocked four days later.

The sources of fry were Buffalo Pound and Diefenbaker Lakes. Fry mortality resulting from transportation problems encountered on 21 May 1987 resulted in a restocking of Jackfish pond on 25 May 1987.

2.4 PHYSIOCHEMICAL MONITORING

Dissolved oxygen and temperature profiles were measured with a YSI oxygen meter as frequently as possible, usually at each pond visit. NH_3 and pH levels were measured using Hach kits. Pond water levels were recorded at the same visit. Visits were usually at weekly intervals. Transparency of water was measured with a Secchi disc at two week intervals.

In addition, water samples for water quality and bacteriological analyses were collected from Meadow Lake Pond and the receiving water body (Meadow River) prior to and near the end of pond drawdown. The samples were immediately placed in coolers chilled with ice and shipped to the Provincial Laboratory, Department of Health, for analyses.

2.5 BIOLOGICAL SAMPLING

2.5.1 Plankton

Surface plankton samples were taken prior to first pond fertilization and weekly thereafter, until the end of June. The samples were concentrated by filtering 100 L of pond water through a plankton net made of No. 20 bolting silk (80 µm mesh) using a calibrated 10-L plastic pail. Five open water and five inshore locations were sampled. One concentrated 100 L plankton sample per pond visit was obtained and preserved in 5% formalin. Zooplankters in the samples were identified and enumerated using a Sedgewick-Rafter cell. The concentrations (no./L) of the various copepods (including nauplii), cladocerans, rotifers and *Chaoborus* were recorded.

Where possible, lengths of 50 individuals from each species of Cladocera and Copepoda were measured. Cladocera were measured from the anterior edge of the head to the posterior margin of the carapace. Copepods were measured from the anterior edge of the head to the posterior edge of the caudal ramus. Measurements (to the nearest 0.04 mm) were done under a stereomicroscope, equipped with a calibrated Whipple ocular micrometer.

2.5.2 Fingerlings

Walleye fingerlings were sampled several times during the growing season with seine and trap nets. Sampling was on a weekly basis beginning two weeks after stocking. Samples were preserved in 10% formalin for subsequent laboratory analysis. Total

lengths and fork lengths (measured to the nearest 0.5 mm) of at least 50 fish, and average weight (bulk weight of sample divided by sample size) were measured at the laboratory immediately upon arrival.

Stomach contents were determined by analyzing at least 30 fingerlings from each sample. All zooplankters were identified and enumerated. Their minimum, maximum and average length were measured to obtain size classes for estimating utilized plankton forage. Insect and fish forage were identified to family (or genus where possible).

2.5.3 Pond Conditions

General pond conditions were qualitatively monitored for abundance of insect forage and extent of emergent growth, and green and blue green algae proliferation.

2.6 FINGERLING ENUMERATION AND HARVEST PROCEDURES

Population estimation of walleye fingerlings in Codette Pond was done using a mark-recapture method described in Ricker (1975). Trapnets patterned after Beamish (1972) were set in water currents (created by pumping water) to catch sufficient walleye for marking (Jensen 1981). Clipping of the left pelvic fin was used for a mark. Fingerlings were kept in tubs of pond water and slightly immobilized with MS 222 (tricane methane-sulfonate). A subsample of the marked population (n=1500) was caged for 12 hours to monitor post-marking mortality. The short term effects of finclipping were found to be negligible. Experiments by Liaw (1984),

Campbell and Rowes (1980), and Churchill (1963) on finclipped fingerling survival had similar results. All marked fish were returned to the pond to allow the marked and unmarked fingerling populations to mix. Four days later, sufficient numbers (for population estimation) of fingerlings were again captured and examined for marks. A population estimate was obtained using the adjusted Petersen method (Ricker 1975). Fingerlings were released by opening the control gate and allowing the pond to drain into Codette Reservoir.

Population estimates for Jackfish and Meadow Lake Ponds were accomplished by weighing several subsamples of the walleye population of each pond in order to obtain an average number of fish per unit weight in each pond. Once an average number of fish per unit weight was established, a total weight of fish produced was measured by bulk weighing the walleye as they were released from the rearing ponds. Subsamples of fingerlings were counted and weighed during each day of harvest to account for fingerling growth over the harvesting period. Fingerlings produced by Jackfish Pond were captured using a trap net placed in the drainage ditch leading to Jackfish Lake, enumerated, and then released downstream of the trap net.

Fingerlings from Meadow Lake Pond were concentrated in capture ponds, and collected by seining. They were then enumerated and placed in 450L distribution tanks (with oxygen and agitation), transported, and stocked in Greig Lake.

3. RESULTS

3.1 LIMNOLOGICAL OBSERVATIONS

3.1.1 Water Temperature, Dissolved Oxygen, pH and un-ionized Ammonia

Figures 4-6 depict temperature and oxygen profiles in the rearing ponds. Because of the shallowness of the ponds, water temperatures and dissolved oxygen concentrations did not vary much with depth on any particular day sampled. Temporally, the oxygen levels and temperature did vary between sampling periods in the same pond and between ponds.

Table 3 presents the ranges and means of water temperature, dissolved oxygen, pH and ammonia in the rearing ponds. The mean pond temperature at the time of stocking was 16.4°C which was 3.4°C above the water temperature at the provincial hatchery. Thus there was sufficient time for the fry to acclimate to pond temperature while in transit. The mean pond temperatures were close to the 18-24°C range recommended for intensive walleye culture (Krise and Meade 1986), but were somewhat lower than the 22°C optimum temperature for juvenile walleye growth determined by Hokanson and Koenst (1986) under laboratory conditions.

Dissolved oxygen levels were adequate in the ponds throughout most of the growing period. Persistent cloudy, rainy weather reduced oxygen levels in Codette (3.4 mg/L), Jackfish (4.2 mg/L) and Glaslyn (3.4 mg/L) Ponds to near critical levels (3.0 mg/L) between 9-11 June (Stickney 1986).

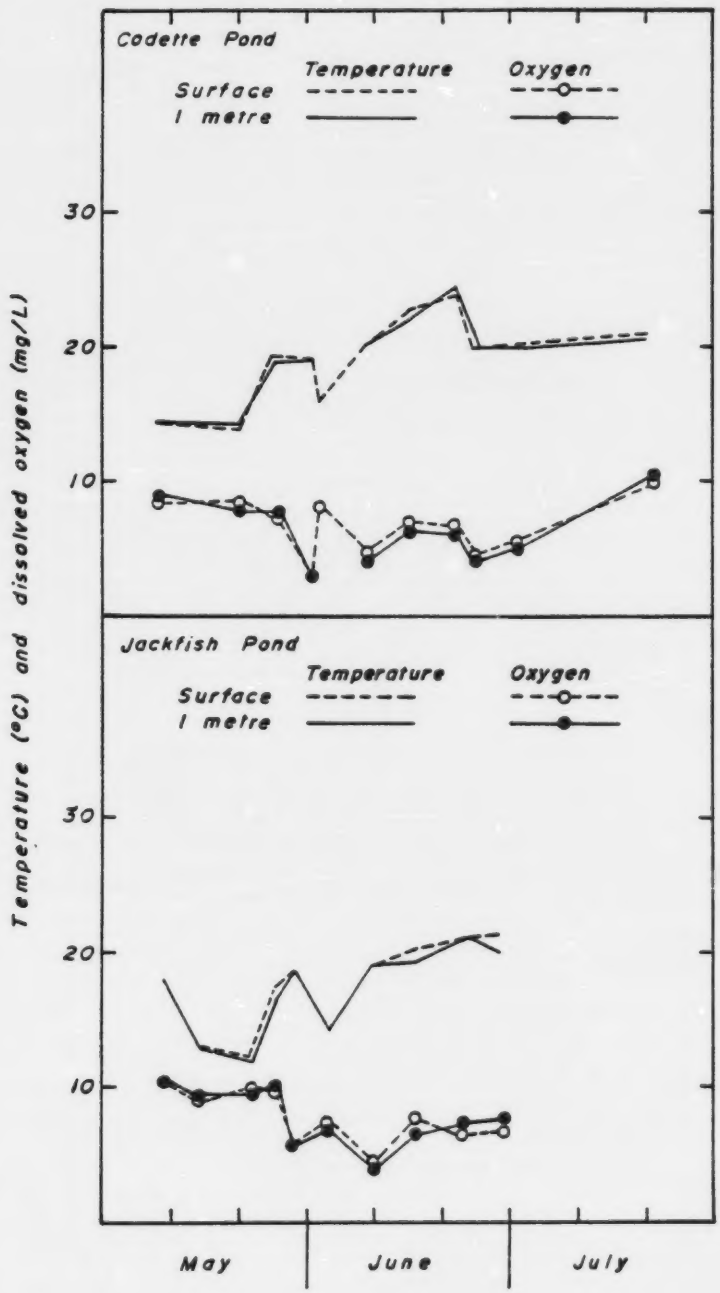


Fig. 4 Changes in water temperature and dissolved oxygen concentrations in Codette and Jackfish Ponds.

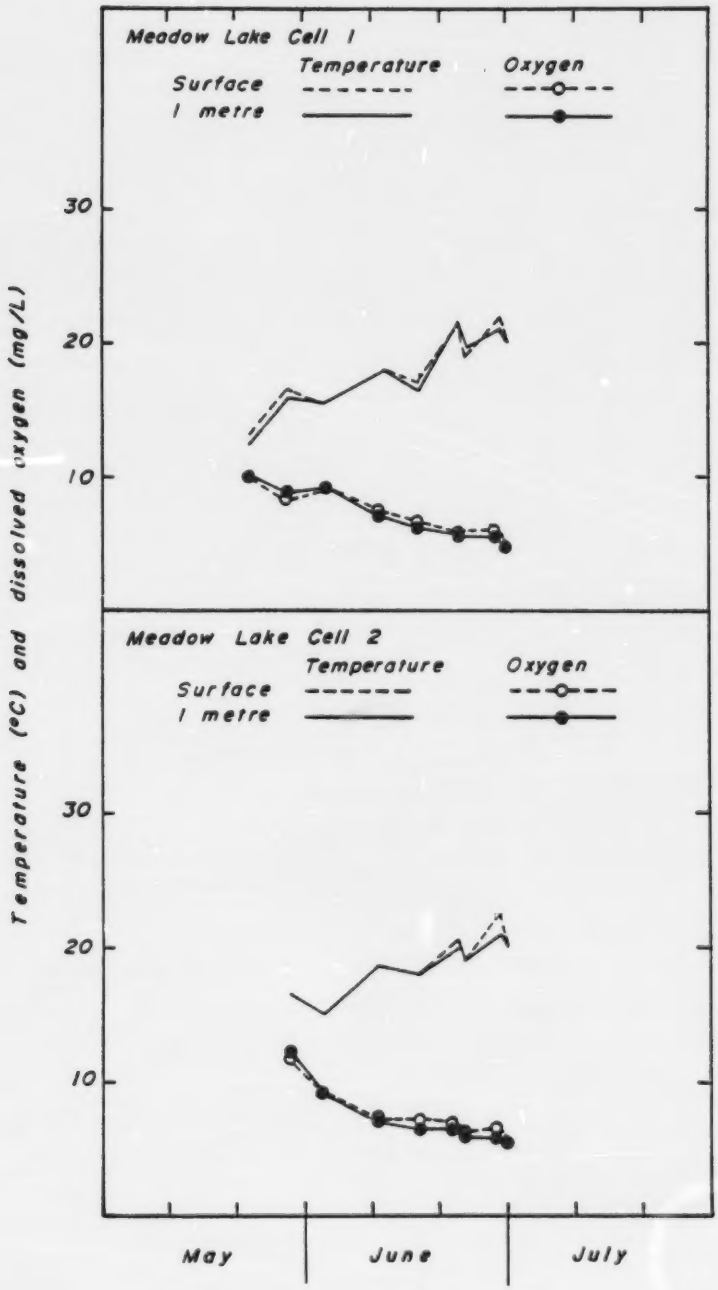


Fig. 5 *Changes in water temperature and dissolved oxygen concentrations in Meadow Lake Pond.*

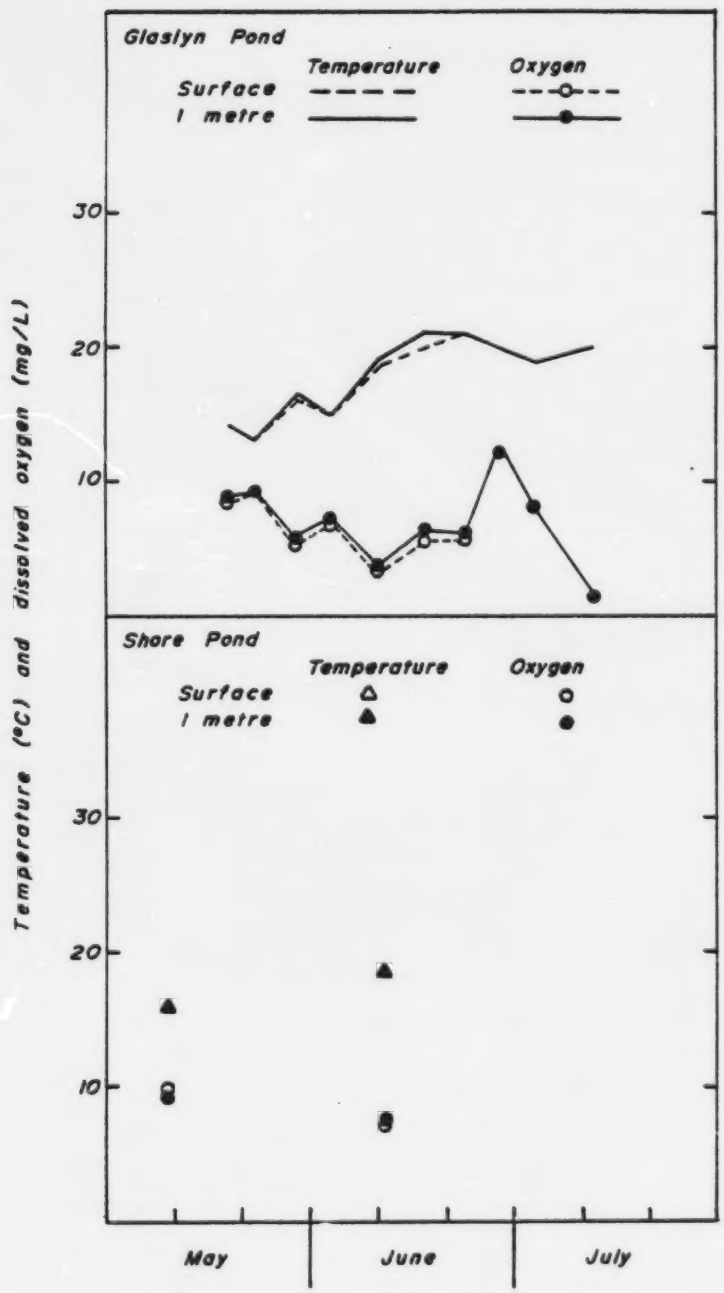


Fig. 6 Changes in water temperature and dissolved oxygen concentrations in Glaslyn and Shore Ponds.

Table 3. Surface water temperature, dissolved oxygen, pH and un-ionized ammonia (NH_3) in rearing ponds: May-June 1987.

Pond	Temperature(°C) (Daytime) Range	Mean	Dissolved Oxygen(mg/L) Range	Mean	pH Range	Mean	Un-ionized Ammonia (mg/L) Range	Mean
Codette	14.25-24.0	19.0(11)	3.4-10.0	6.5(11)	7.8-8.7	8.2(10)	0.12-1.3	0.66(10)
Jackfish	12.5-21.5	17.25(10)	4.2-9.7	7.5(10)	7.9-8.7	8.4(9)	0.24-2.8	1.09(9)
Meadow Lake - Cell 1	13.0-22.0	18.1(9)	5.0-10.0	7.6(7)	7.8-8.4	8.1(7)	0.24-2.64	0.97(7)
Meadow Lake - Cell 2	15.0-22.5	18.5(8)	6.6-11.8	8.1(6)	7.8-8.4	8.1(6)	0.42-1.3	0.80(5)
Glaslyn	13.0-21.0	17.0(7)	3.4-9.2	6.6(7)	7.9-8.5	8.2(5)	0.36-2.9	1.3(5)

N.B. Number of measurements taken is in brackets.

All ponds were alkaline, falling within the 7.8 to 8.7 pH range. The Meadow Lake Ponds had the smallest range; Glaslyn was intermediate, while Codette and Jackfish had the widest range (Table 3).

Un-ionized ammonia levels varied greatly between ponds, Codette having the lowest mean level (0.66 mg/L) and Glaslyn having the highest mean ammonia level (1.3 mg/L) during the growing period.

Toxic concentrations of un-ionized ammonia for short-term exposure are between 0.6 and 2.0 mg/L for most species (Boyd 1982). In Glaslyn pond, ammonia levels were as high as 2.9 mg/L. Ammonia is more toxic to fish when the dissolved oxygen concentration is low. See section 4.3.1 for a more complete discussion of un-ionized ammonia. Examination of field notes shows that when Codette and Glaslyn had the same low DO (3.4 mg/L) levels (temperature and pH were also the same), the ammonia levels were much higher in Glaslyn (2.2 mg/L) as compared to Codette Pond (0.6 mg/L).

3.1.2 Water Quality

To assess the impact of releasing Meadow Lake rearing pond water on the water quality of the receiving water body, the Saskatchewan Department of Environment and Public Safety required monitoring of certain water quality variables. The data are presented in Appendices 1-4.

Chemical analyses of water indicated that both rearing pond cells appeared to have higher concentrations of chemical substances and nutrients than the receiving water body (Meadow

River), particularly regarding sulphate, Kjeldahl N, total hardness, suspended solids, and B.O.D. This is likely due to erosion and the response of bottom sediments to drawdown procedures.

As described by Liaw (1987), bacterial counts are highly variable. Therefore, results from the low frequency samplings do not permit meaningful comparisons between the water sources (ie. rearing pond and drainage ditch) and the receiving water body (Meadow River).

3.1.3 Net-Plankton Standing Crop

Changes in net-plankton standing crop (copepods and cladocerans only) are presented in Fig. 7-9. Plankton concentrations were monitored weekly to assess the effects of fertilization on, and abundance of, total and usable walleye forage. A minimum prey selection size of 0.45 mm in length was used to determine the proportion of zooplankton suitable for utilization by walleye, where walleye samples were not obtained for stomach analysis (Arsenault 1987, Liaw 1984, Hokanson and Lien 1986). Analyses of fingerling stomach contents were used to determine the proportion of zooplankters utilized for the remainder of the growing season. Rotifers and copepod nauplii are excluded from the plots as they are rarely consumed because of their small size (Liaw 1987). Large differences between total and usable forage in Jackfish and Meadow Lake ponds are predominantly due to the presence of large numbers of *Bosmina* which were too small to be utilized as forage and consequently were not found in walleye stomach contents in any great number. Therefore, changes in species composition and relative

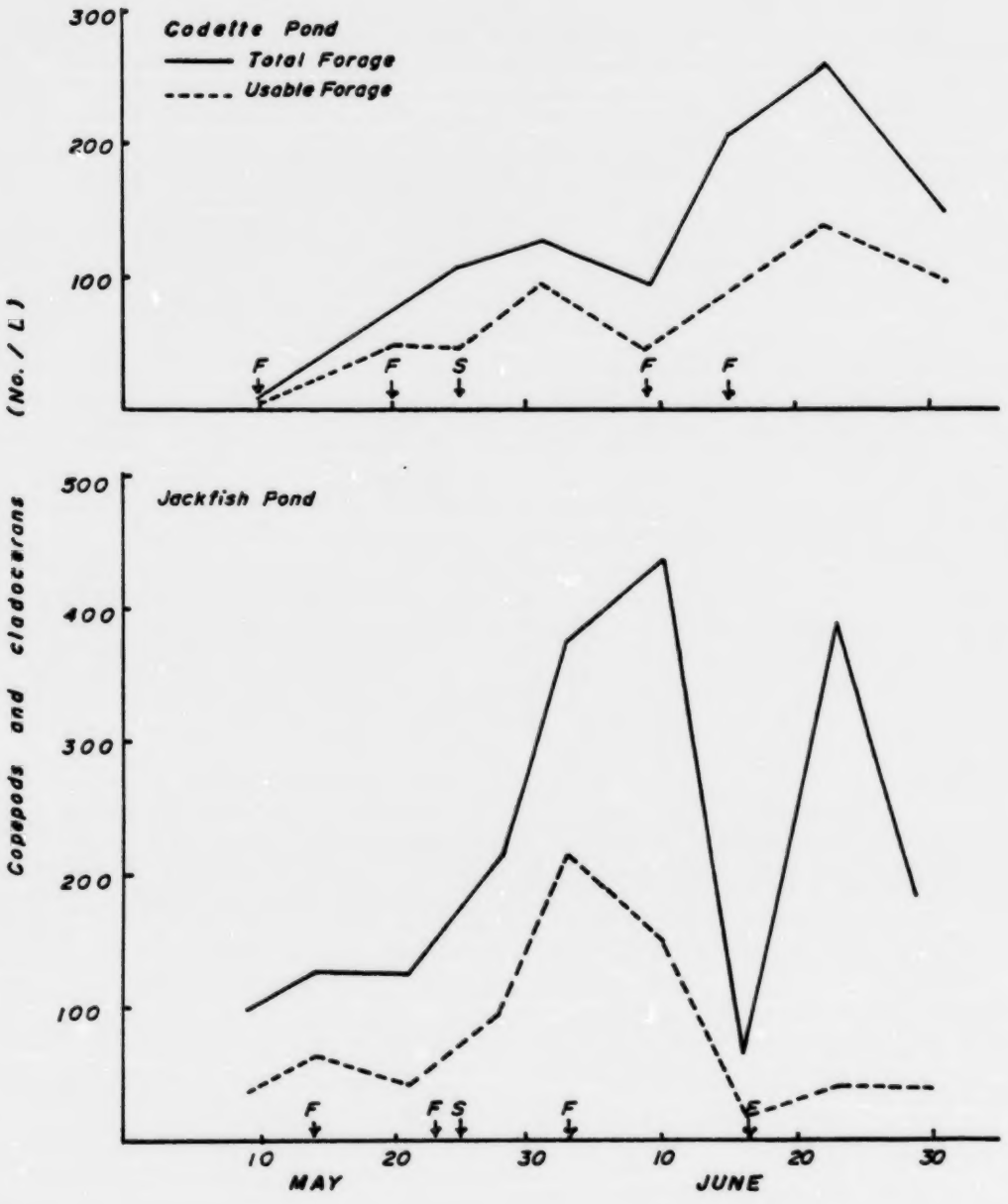


Fig. 7 *Changes in standing crop of copepods (excluding nauplii) and cladocerans in Codette and Jackfish Ponds. Arrows indicate dates fertilized (F) or stocked (S).*

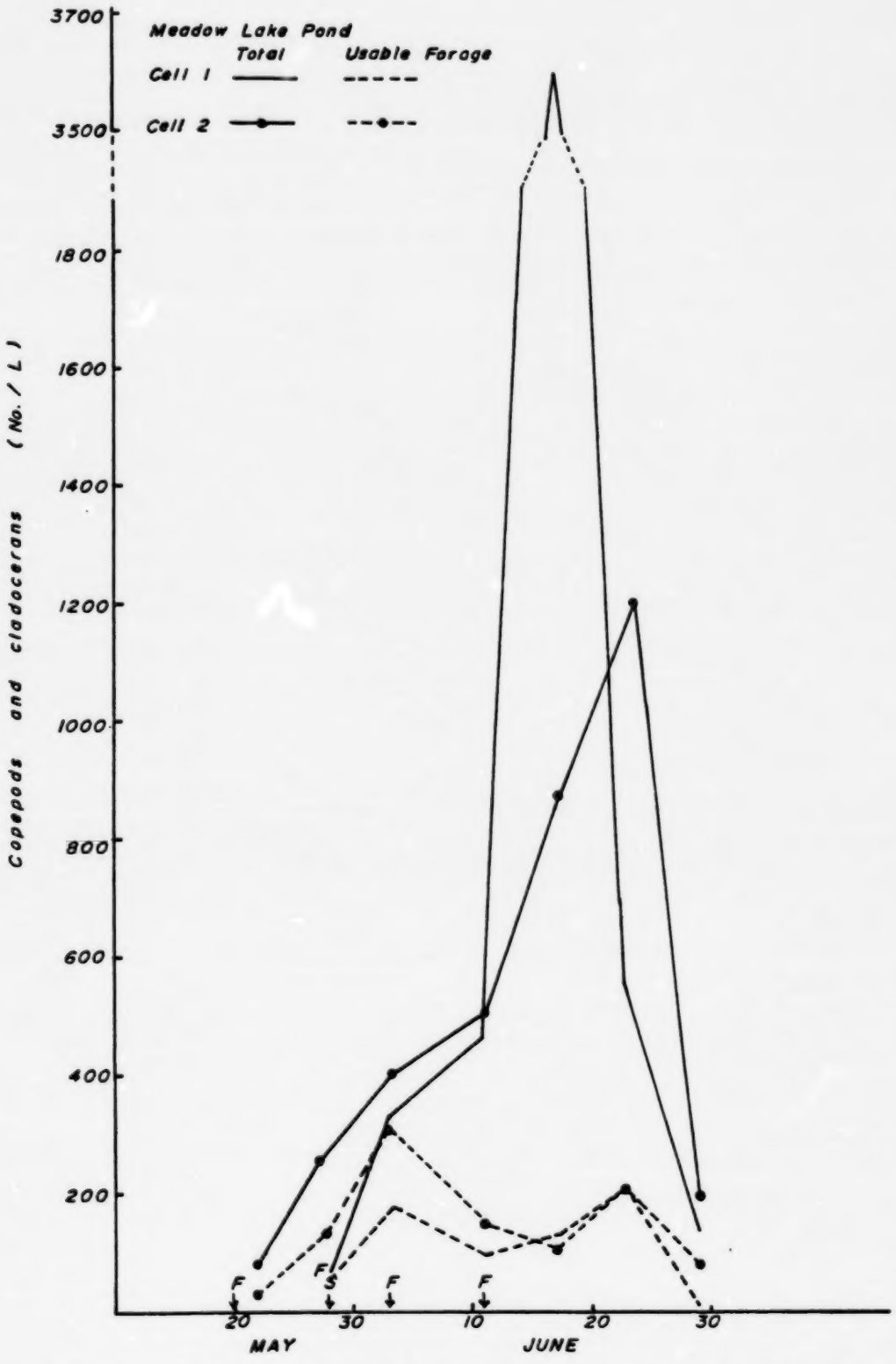


Fig. 8 Changes in standing crop of copepods (excluding nauplii) and cladocerans in Meadow Lake Pond. Arrows indicate dates fertilized (F) or stocked (S).

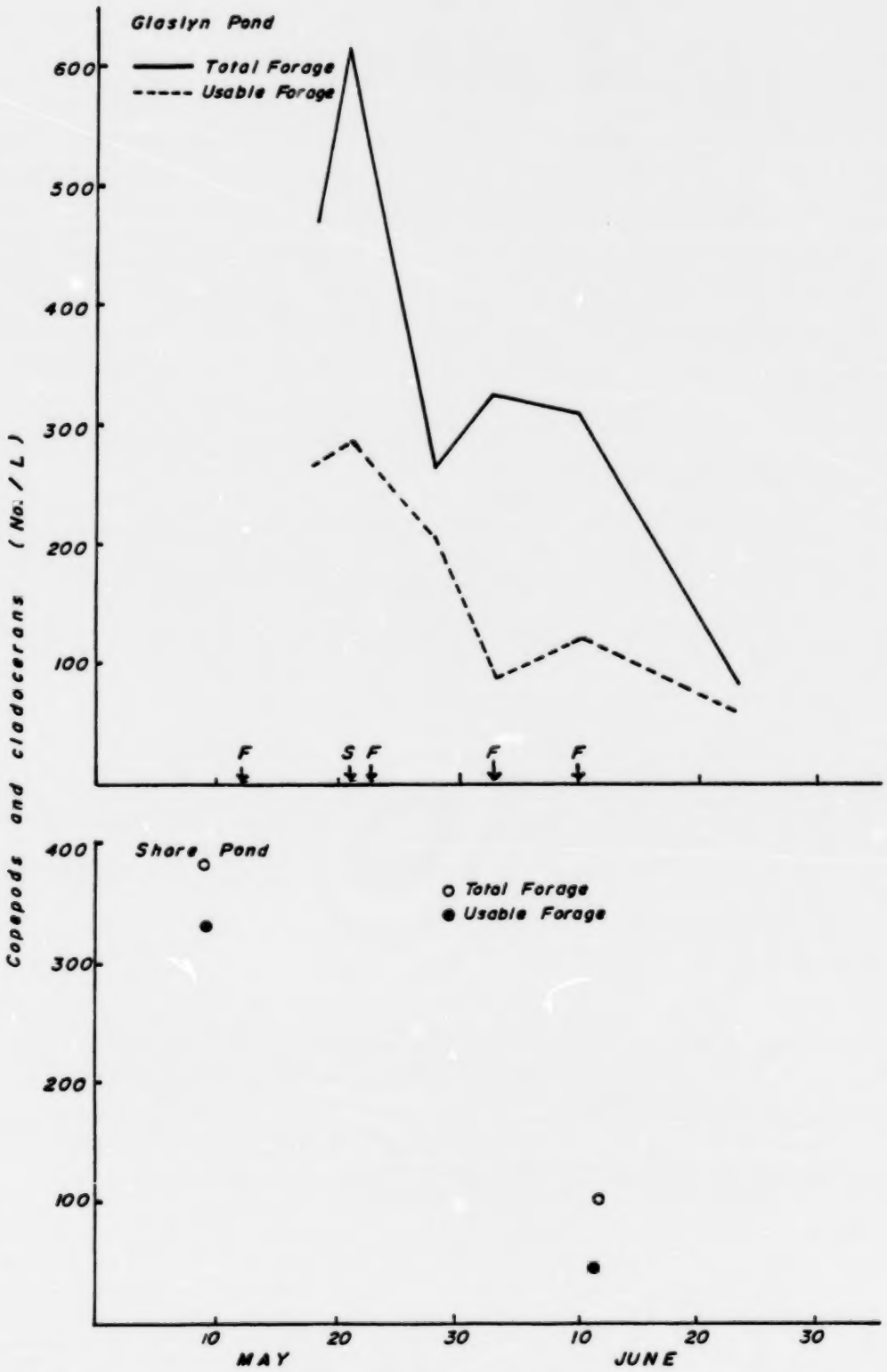


Fig. 9 Changes in standing crop of copepods (excluding nauplii) and cladocerans in Glaslyn and Shore Ponds. Arrows indicate dates fertilized (F) or stocked (S).

abundance of copepod and cladoceran species would have a significant effect on the size frequency distribution of the crustacean zooplankton population, and hence, the amounts of usable forage available to walleye (Liaw 1987).

3.2 FINGERLING PREY SELECTIVITY

Pond stocking in late May was just prior to or during the initial plankton bloom (Fig. 7-9). Li and Mathias (1982) and Liaw (1987) suggest that usable zooplankton densities >100 organisms/L during the initial stage of walleye growth are required to foster good fingerling production. This would allow maximum opportunities to develop a prey searching image (Arsenault 1987), and a good initial feeding response. The planktonic forage base was adequate in all the fertilized rearing ponds during this period, as determined by stomach analyses.

Figures 10-13 present results of stomach content analyses of walleye from Codette, Jackfish and Meadow Lake Ponds. The data are expressed as percent frequency of occurrence.

Copepods and cladocerans (daphnids) were the major component of the walleye diet during the first few weeks after stocking. Cyclopoid copepods were the principal copepod selected although some calanoids were also taken. *Daphnia* was the principal cladoceran selected although there was some reliance on *Ceriodaphnia* and *Moina* in both cells of Meadow Lake Pond. About 3 weeks after stocking, insects became increasingly important in the diet.

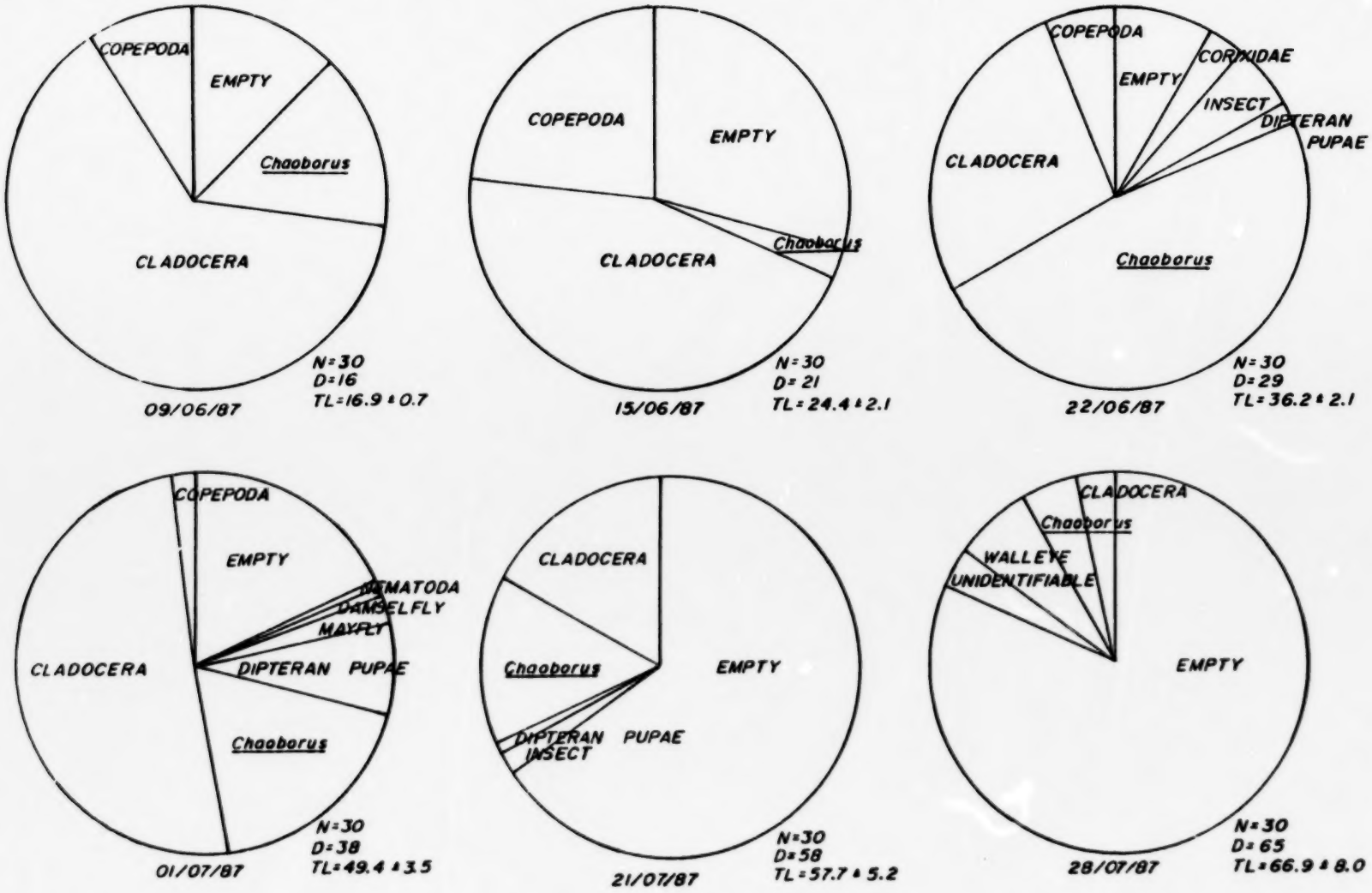


Fig. 10 Codette Pond, 1987. Frequency of occurrence of various food items in walleye fingerling stomach contents. N = number of walleye examined. D = days in pond. TL = total length, mm ($\bar{X}$ ± SD).

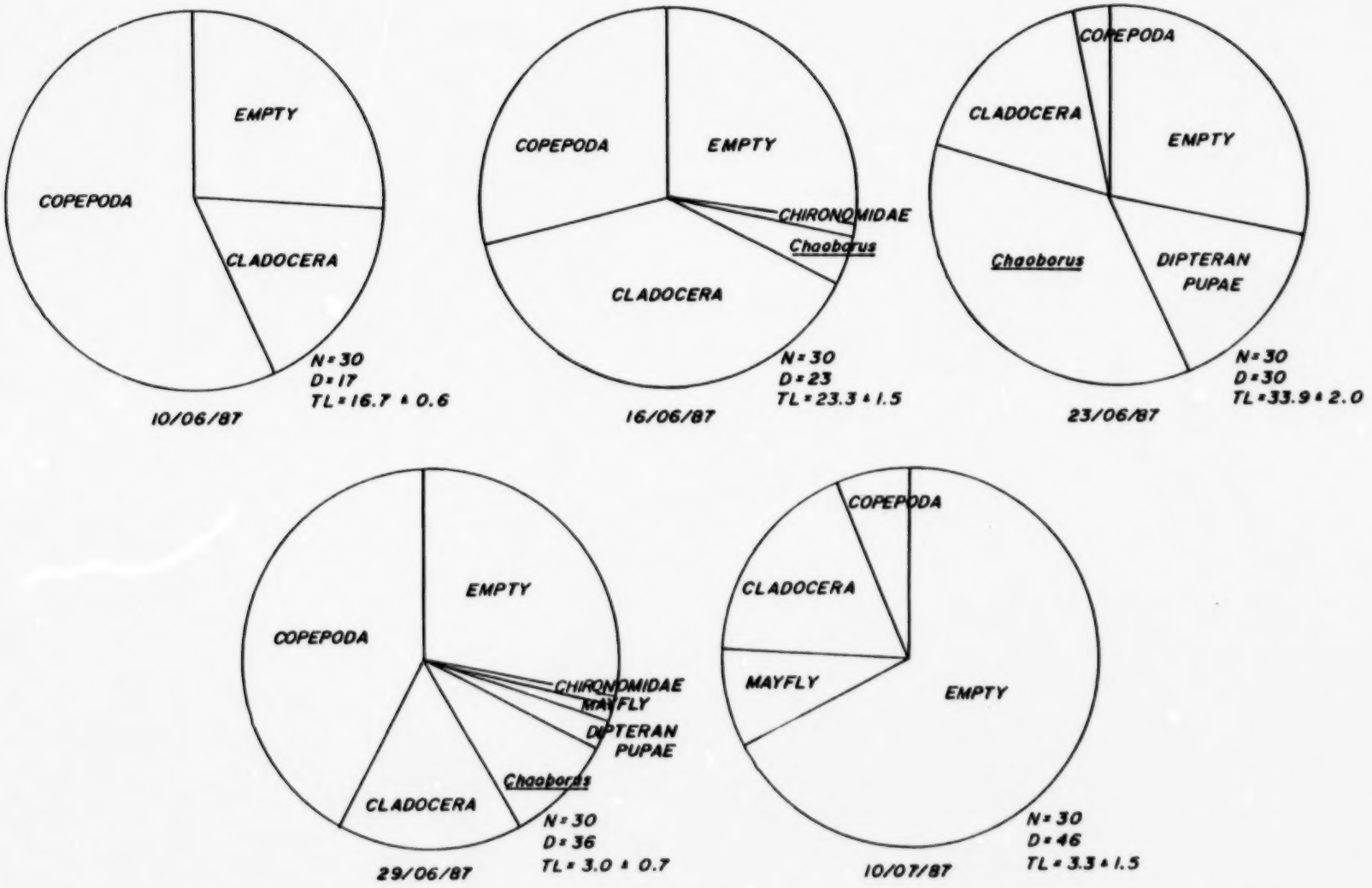


Fig. 11 *Jackfish Pond, 1987. Frequency of occurrence of various food items in walleye fingerling stomach contents. N = number of walleye examined. D = days in pond. TL = total length, mm ($\bar{X}$ ± SD).*

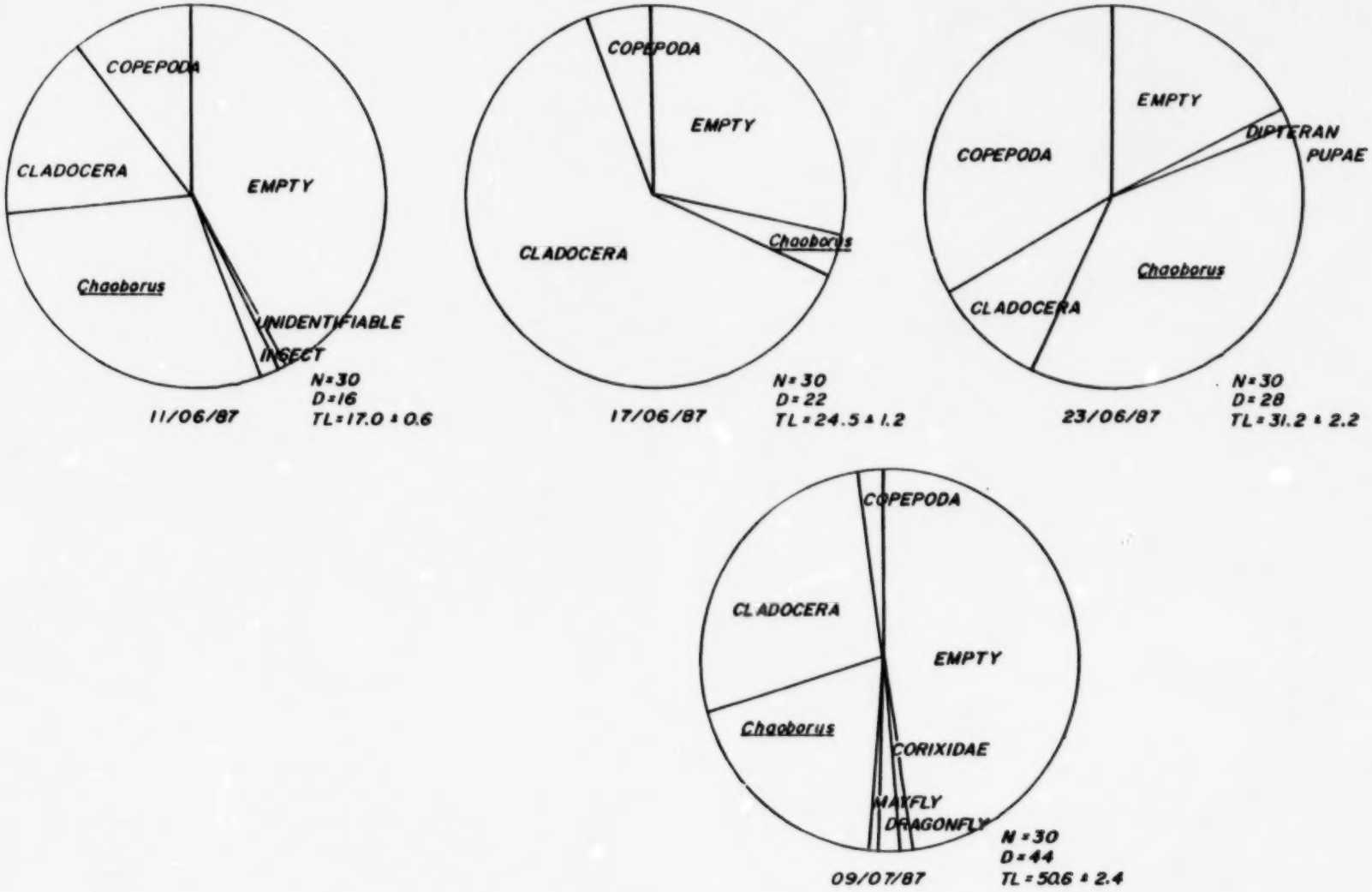


Fig. 12 Meadow Lake Pond - Cell 1, 1987. Frequency of occurrence of various food items in walleye fingerling stomach contents. N = number of walleye examined. D = days in pond. TL = total length, mm ($\bar{X}$ ± SD).

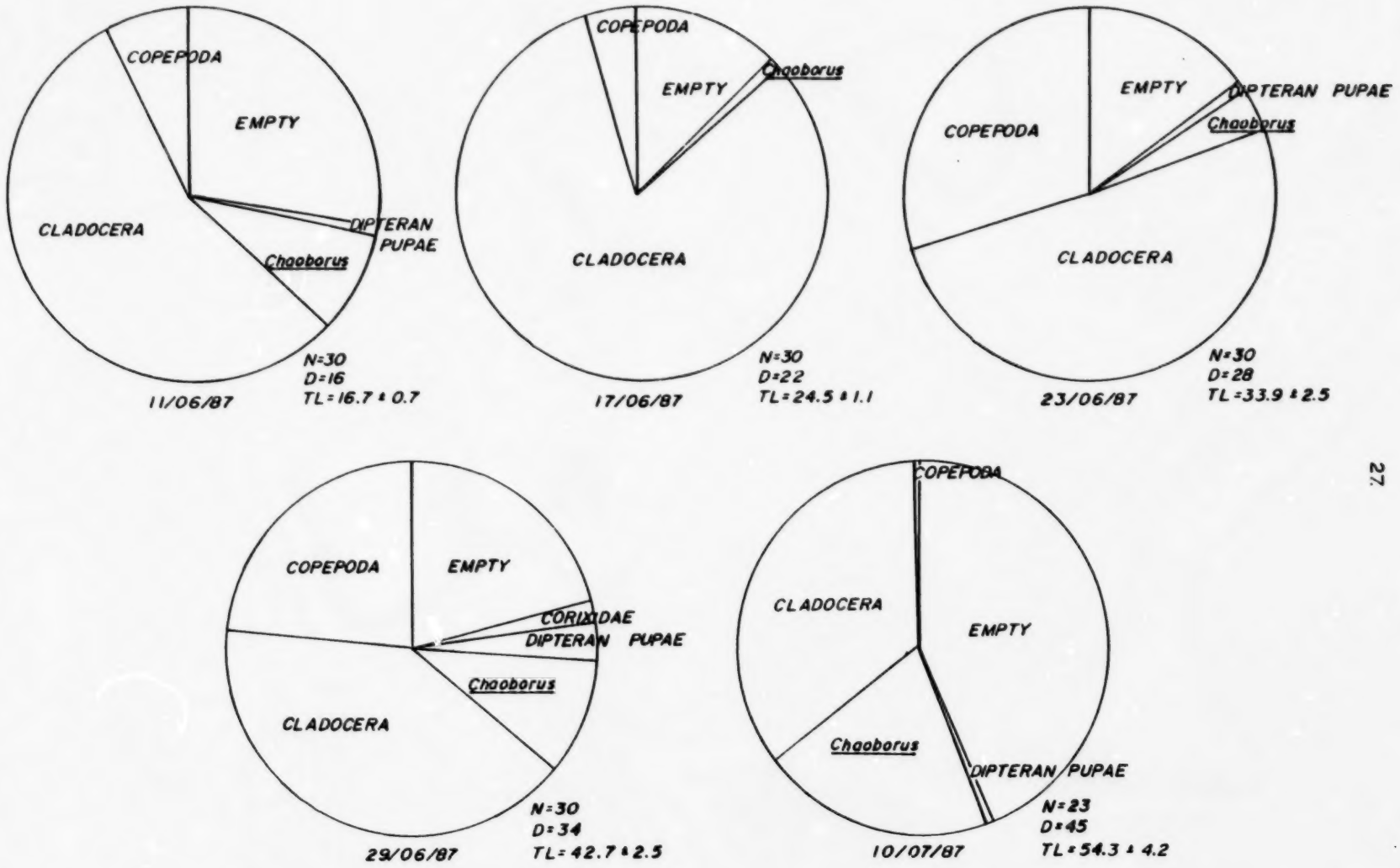


Fig. 13 Meadow Lake Pond - Cell 2, 1987. Frequency of occurrence of various food items in walleye fingerling stomach contents. N = number of walleye examined. D = days in pond. TL = total length, mm ($\bar{X}$ ± SD).

Chaoborus was the principal insect larvae consumed but as the fingerlings grew, other dipteran larvae and pupae were selected, as well as mayfly, damselfly and dragonfly larvae, chironomids and corixids. This illustrates a gradual diet shift to a larger sized prey. Copepods and cladocerans were frequently taken throughout the growing season. At 9 weeks after stocking Codette Pond fingerlings showed evidence of cannibalism, indicating a depleted forage base and a shift from an insect to a fish prey selection. The effects of cannibalism were minimal on the walleye population as determined by stomach analyses.

3.3 FINGERLING GROWTH

Length and weight growth curves of walleyes sampled in the rearing ponds during the growing season are presented in Fig. 14 and 15. Growth in both length and weight, over a 9 week period was slightly sigmoidal, with the point of inflection being around 6 weeks into the growing season. Stomach analyses of fingerlings sampled at and after this time indicate that food supplies were beginning to decrease. Both curves were fitted by eye. Data points were based on sample sizes ranging from 24 to 75 fingerlings ($\bar{X}$=50). Growth development falls within the ranges detailed by Liaw (1987).

During the growing period, walleye fingerlings gained an average of 1.0 mm/day. From Fig. 15 the average weight gains of the fingerlings was 0.5 g/day between 20 and 60 days of growth

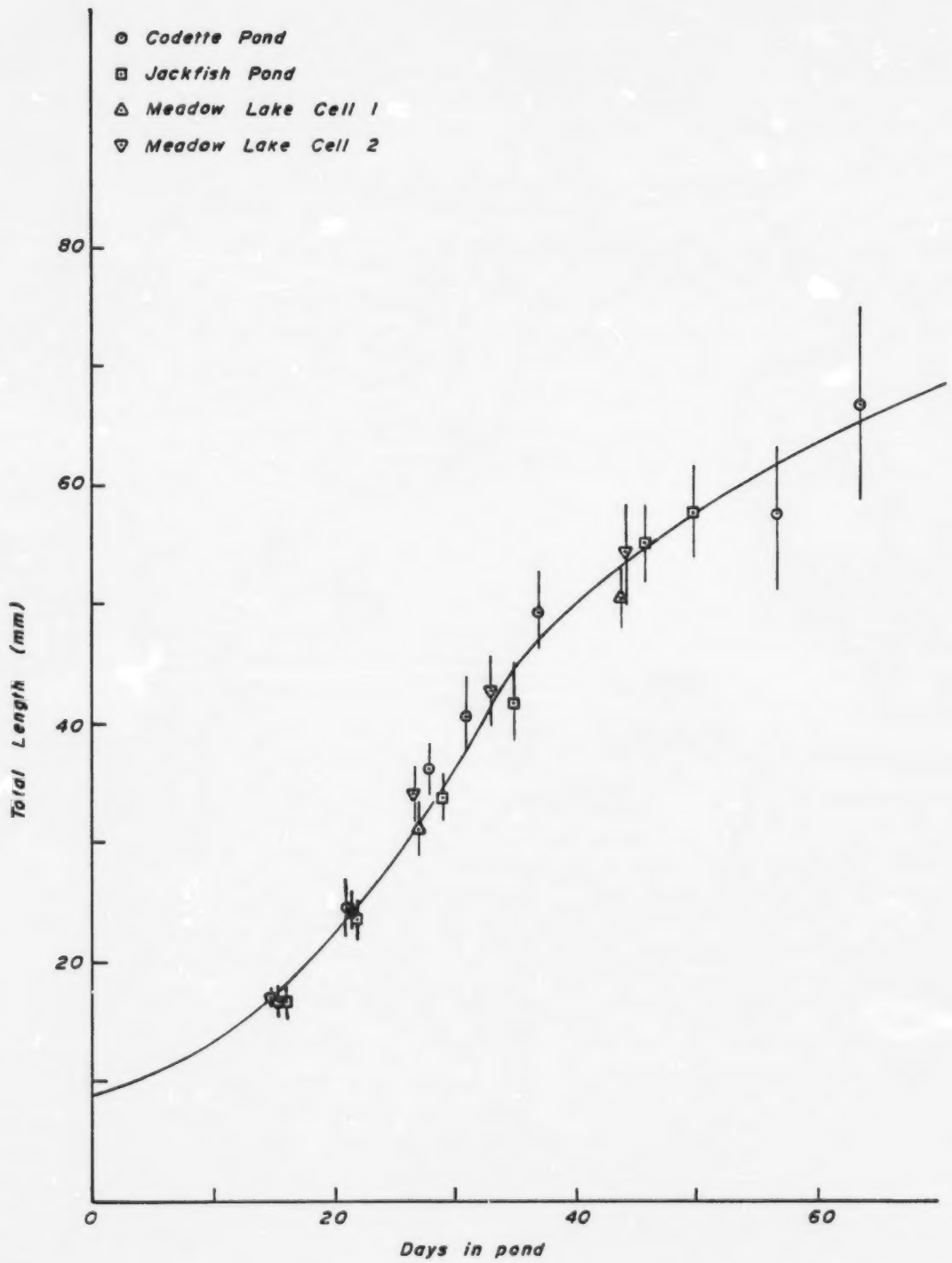


Fig. 14 Length of walleye fingerlings. The curve fitted by eye illustrates the general growth trend. Sample sizes range from 24 to 75 ($\bar{x}$=50). The bars represent standard deviations within samples.

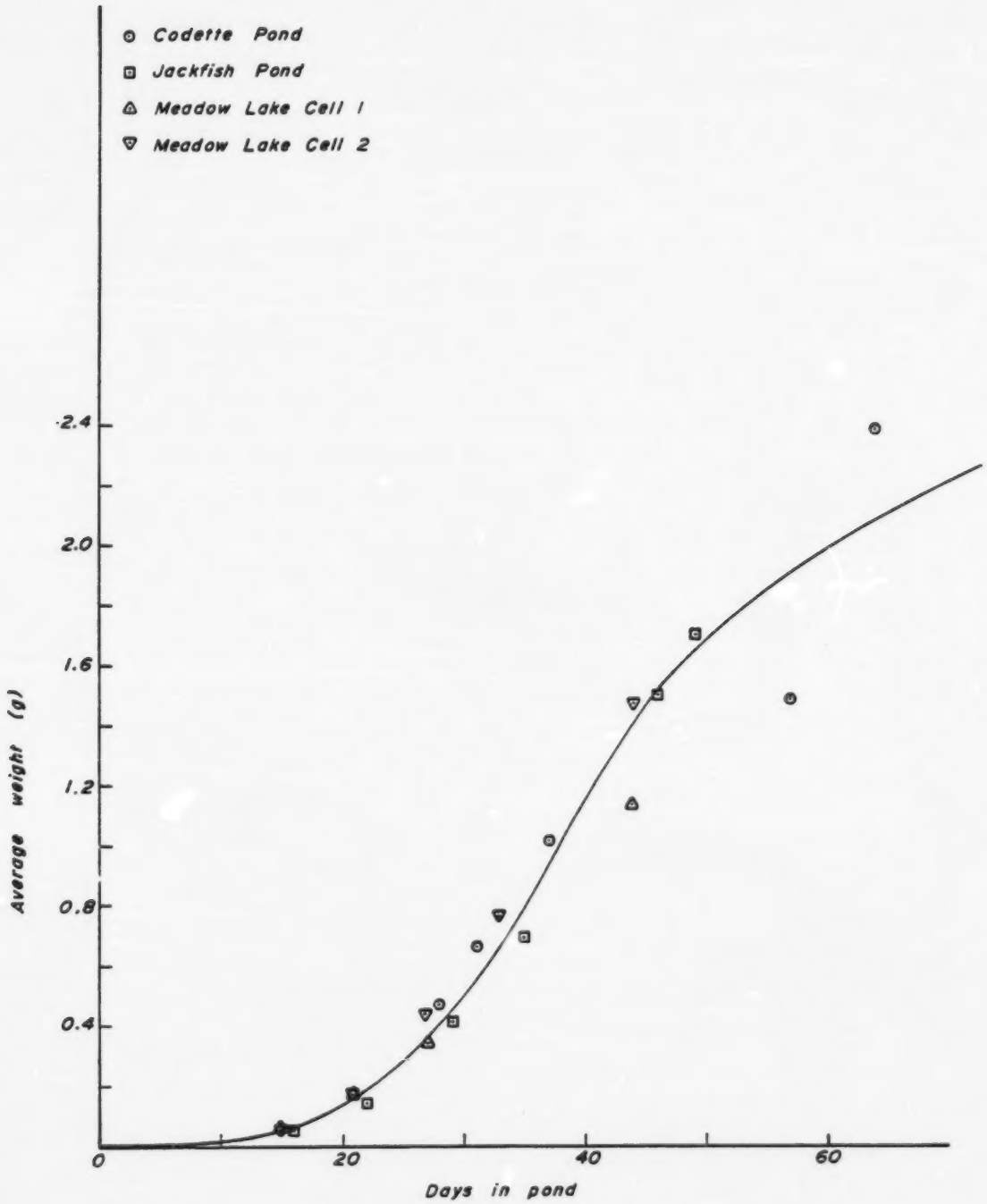


Fig. 15 *Weight of walleye fingerlings. The curve fitted by eye illustrates the general trend of weight increase. Sample sizes range from 24 to 75 ($\bar{x}$ = 50).*

in the ponds, which is slightly less than the 0.06 g/day calculated over the same period from Fig. 9 in Liaw (1987).

Appendix 5 presents the 1987 fingerling length and weight data collected from the rearing ponds.

3.4 SURVIVAL AND PRODUCTION

Pond production is summarized in Table 4. Walleye survival from fry to fingerling size ranged from 0 in Glaslyn Pond to 54% in Meadow Lake Cell 2. Population density ranged from 0 in Glaslyn to 27 000 fingerlings/ha (39.9 kg/ha) in Meadow Lake Cell 2. An overall survival rate of 29.5% and an overall production of 9112 fingerlings/ha was obtained from the five ponds.

3.5 HARVESTING AND RESTOCKING

An estimated 335 300 fingerlings were produced in 1987 from Codette, Jackfish and Meadow Lake Ponds. Of these 188 239 fingerlings were released into Codette Reservoir; 49 585 were released into Jackfish Lake and 97 480 were released into Greig Lake.

3.6 FINGERLING PREDATION

Young-of-the-year pike *(Esox lucius)* and burbot *(Lota lota)* were inadvertently introduced to both cells of Meadow Lake Pond during spring pumping operations. Estimated population densities of pike at pond harvest were 257/ha in Cell 1 and 41/ha in Cell 2 of Meadow Lake Pond. Estimated densities of burbot were 1.6/ha in Cell 1 and 2.8 in Cell 2. Stomach analyses of 20 pike

Table 4. Percent survival and estimated population density and yield of walleye fingerlings, 1987.

Pond	Harvest Dates	Days in Pond	Estimated No. Fry Stocked	Population Estimate	95% Confidence Limit	Percent Survival	Population Density (no/ha)	Yield* kg/ha
Codette	27-30 July	66	500 000	188 239	±18 607	37.6	18 824	45.00
Jackfish	9-14 July	50	200 000	49 585	-	24.8	3 814	6.55
Meadow Lake - Cell 1	8-14 July	48	155 000	280	-	0.2	45	0.05
Meadow Lake - Cell 2	7-14 July	48	180 000	97 200	-	54.0	27 000	39.90
Glaslyn	15-16 July	56	100 000	0	-	0	0	0
TOTAL			1 135 000	335 304		29.5	9 112	

* Based on average weight of fingerlings at harvest.

(captured 3 weeks after stocking walleye) showed 2% of pike contained walleye, 78% contained insect larvae *(Chaoborus* and chironomids) and 20% had empty stomachs. Five weeks after stocking, an additional 60 pike were trapped and examined. Stomach analyses showed 7% of pike contained walleye, 23% contained insects (chironomids and corixids) and 70% had empty stomachs. During drawdown in mid-July, heavy tern predation on Cell 2 was noted during daylight hours but was not quantified.

Several fish species were inadvertently introduced to Jackfish Pond. The estimated pike density at harvest was 23/ha and for burbot was 5.0/ha. Stomach analyses of 60 pike captured during harvest operations showed that walleye were not the preferred diet of pike, as 2% contained walleye, 23% contained spottail shiners *(Notropis hudsonius)*, 15% contained brook sticklebacks *(Culaea inconstans)* and 60% had empty stomachs. Stomach analyses of burbot indicated a diet of mayflies and *Chaoborus*. Yellow perch *(Perca flavens)* young-of-the-year had an estimated density of 410/ha at harvest. The perch were still planktivorous and insectivorous. Whitefish *(Coregonus clupeaformis)* and cisco *(Coregonus artedii)* were also present in low numbers. Tern and gull predation during harvest was heavy during daylight hours.

Codette Pond did not have any predatory fish other than larger walleye fingerlings which began to cannibalize at harvest time. Stomach analyses of 30 fingerlings revealed 7% contained walleye (see Fig. 11). The only other fish species present were common suckers *(Catostomus commersoni)* and quillback *(Carpiodes cyprinus)*.

4. DISCUSSION

4.1 POND BIOMECHANICS

The intent of pond fertilization is to produce and maintain a large zooplankton forage base during the period when fingerlings are planktivorous - from the period of initial fry stocking to several weeks following. Previous studies have found that some planktonic forms (rotifers, copepod nauplii, *Bosmina* and *Ceriodaphnia*) are not utilized as forage because of their small size (Arsenault 1987, Liaw 1987). Fish always select the largest food item they can ingest and as they grow the optimum size of the food item also increases. This size selection is due in part to an increase in distance between the gill rakers which allow smaller particles to pass through, and also to the fact that smaller food items become less energy efficient as the walleye grow (Rutledge 1984, Beagon and Mortimer 1981). Because of this size selection, enumeration of usable zooplankton density as described in section 3.1.3 provides a better forage estimate than total zooplankton density.

Examination of data in Fig. 7-9 indicates a generally low forage base prior to initial pond fertilization. Walleye initially rely on copepods as forage. Calanoid copepods do not have multiple overlapping generations but *Cyclops* reproduce throughout the year (Rutledge 1984). To promote a large copepod population timed to coincide with fry stocking, a heavy initial fertilization 10-12 days before stocking was applied (see Section 2.2). All ponds responded to fertilization although the intensity and magnitude was variable.

Cladocerans have overlapping generations, the generation time varying from 7 to 8 days at 20°C depending on species (Rutledge 1984). Cladocerans (principally daphnids) are known to be one of the major food items found in the fingerling diet for the first several weeks in the pond. Therefore timed applications of organic fertilizer were used to help sustain the daphnid populations for extended periods at artificially higher numbers. Rutledge (1984) examined the response of zooplankton populations to fertilization in some detail. He found that manipulation of zooplankton populations through fertilization involves many complicated and constantly changing chemical and biological reactions, making it difficult to predict the effects of fertilization.

A comparison of usable zooplankton counts (Fig. 7-9) with the optimal density desired (about 100 organisms/L) indicate adequate zooplankton densities existed in all ponds with the exception of Codette Pond, in which usable zooplankton densities fell to about 50 zooplankters/L 2 weeks after stocking (a result of adding fresh water to mitigate low DO levels). Stomach analyses (Fig. 10) indicate the Codette fingerlings compensated by selecting *Chaoborus* as a supplemental food source. Usable zooplankton levels increased to adequate levels within a few days after fertilizer applications.

Cladocerans and copepods are omnivorous. Cladocerans feed on algae, protozoa and organic detritus. Copepods feed on protozoans, small metazoans, other crustaceans and under some circumstances organic debris. Therefore both groups are major food of larval and small fingerlings, and both compete for a similar

food source (Rutledge 1984). It can then be postulated that the addition of alfalfa pellets provides substrate for bacterial decomposition which stimulates a release of nutrients usable by phytoplankton and bacteria. This results in increased survival and growth of existing zooplankton (allowing more to reach a usable size for walleye consumption in a matter of days). By maintaining an artificially high zooplankton carrying capacity more reproductively mature zooplankton can exist resulting in generation of additional zooplankton. Comparison between fertilized and unfertilized ponds in Saskatchewan have shown that fertilization increases zooplankton production (Liaw 1987). Large and abrupt natural fluctuations in zooplankton densities, walleye prey selection, and varied pond conditions mask the effectiveness of pond fertilization.

Alfalfa pellets have a high C:N ratio (12.59:1) and therefore decompose slowly (Rutledge 1984). Addition of a chemical fertilizer high in nitrogen (such as superphosphate) would speed up the bacterial breakdown of alfalfa pellets and other detritus as well as stimulate phytoplankton growth. The effect of using both organic and inorganic fertilizers is to rapidly produce a high forage base for zooplankters.

Codette Pond is the only pond in which both organic and inorganic fertilizer were added; this pond had the least variation in numbers of zooplankton compared to other ponds (Fig. 7-9). Codette Pond also had a very high algal growth consisting primarily of blue-green algae *Aphanizomenon* and some *Anabaena*. This phytoplankton bloom persisted from early June through pond drawdown,

and was accompanied by a corresponding trend of increase in zooplankton standing crop (Fig. 7). Boyd (1982) states that an increase in primary productivity following fertilization usually results in greater zooplankton abundance. No large algal bloom was observed in any other pond.

Comparison of zooplankton standing crop between Shore Pond (not stocked or fertilized) and the other ponds (Figs. 7-9) show that Shore Pond initially had a high usable zooplankton density which consisted primarily of cyclopoid copepods. A second sampling of zooplankton standing crop taken 1 month later showed low levels of zooplankton present during the period when the zooplankton density was higher in the fertilized ponds. This period corresponds to the first critical period in walleye development - first exogenous feeding and development of a searching image (Arsenault 1987, Krise and Meade 1986, Li and Ayles 1981).

4.2 FINGERLING GROWTH AND PRODUCTION

Growth of fingerlings in the experimental rearing ponds during 1987 was similar to that of previous years as summarized by Liaw (1987). Walleye fingerlings grew an average 1.0 mm/day, very close to that achieved in previous years. Over the same period (20-60 days after stocking) the average weight gain was 0.05 g/day which is slightly less than the 0.06 g/day calculated from Liaw (1987). Overall walleye growth parameters were within limits defined by Liaw (1987) for Saskatchewan ponds.

Observations from the present study suggest that stocking density had little effect on fingerling growth for the period in which they were in the pond culture. Other studies have, however, indicated that not only food and temperature but stocking density can be a strong determinant of walleye growth (Green and Derksen 1982, Campbell and Rowes 1980).

Estimated fingerling densities (no/ha) at harvest time ranged from 0 to 27 000/ha (averaging 9 112/ha). Survival of fingerlings ranged from 0 to 54%, averaging 29.5%. The highest production in terms of fingerling density and percent survival was from Meadow Lake Cell 2. However, when production is expressed in terms of yield (kg/ha), Codette Pond was the most productive, followed by Meadow Lake Cell 2. Production results are summarized in Table 4 of Section 3.6.

Fish culturalists have a choice of producing high numbers of small fingerlings or low numbers of large fingerlings, as a pond's production in terms of kg/area is the same (Clough 1981). Fingerling production in fertilized ponds does not increase in direct proportion to increased fertilizer additions and above a certain level, increasing fertilizer rates does not further increase fish yields (Boyd 1982). The reason is that one or more essential nutrients (N,P,C) is limiting production at lower levels of a pond's food web, or anoxic conditions are created resulting in summerkill. Just as soil nutrient regimes vary from region to region, so do pond nutrient regimes. Thus, a fertilization program that works

perfectly well in one pond may fail if applied to another (Boyd 1982). Only those nutrients that are limiting production should be added to ponds.

Richard and Hynes (1986) state that water source, productivity levels, pond configuration, and organic soil content will vary for each pond ensuring pond carrying capacity will also vary between each pond. They suggest a goal of maximizing the quality of fish produced opposed to quantity.

4.3 SOURCES OF FINGERLING MORTALITY

4.3.1 Water Quality

Hokanson and Koenst (1986) determined 22°C to be the optimum temperature for juvenile walleye growth. Mean pond temperatures were 20.0, 18.0, 18.7, 18.7, 17.5°C for Codette, Jackfish, Meadow Lake 1, Meadow Lake 2, and Glaslyn Ponds respectively. They also found that optimum growth varied from 2-7°C on duplicate tests. According to Stickney (1986) temperatures below 18°C reduce growth rates. Therefore it is unlikely that pond temperatures had any significant adverse effects on walleye growth. At no time was a lethal temperature (>31°C) recorded in the ponds.

Walleye tolerate dissolved oxygen concentrations as low as 2.0 mg/L in the laboratory, though in nature they are generally found at DO levels above 3.0 mg/L (Stickney 1986). Mass mortality has been reported at 4.0 mg/L DO in the presence of hydrogen sulfide

gas (Campbell and Rowes 1980). Laarman and Reynolds (1974) state a healthy walleye population requires at least 5.0 mg/L DO. DO levels as low as 3.4 mg/L in Codette and Glaslyn Ponds and 4.2 mg/L in Jackfish Pond were recorded. This probably precipitated a fish kill in Glaslyn Pond and partial kill in Jackfish Pond as lethal un-ionized ammonia levels (2.2 and 2.8 mg/L respectively) were associated with the low DO levels. Ammonia levels were low in Codette Pond (0.6 mg/L). Un-ionized ammonia is more toxic when the DO concentration is low.

Toxic concentrations of ammonia for short term exposure are between 0.6 and 2.0 mg/L for most fish species (Boyd 1982). Un-ionized ammonia is highly toxic to fish and the proportion of the total ammonia nitrogen existing as un-ionized ammonia increases with increasing temperature and pH (Thurston et al 1979). Boyd (1982) further states that the influence of pH is greater than the effect of temperature on ammonia levels. As stated in the results section, pH was similar in all the rearing ponds.

As the ammonia level increases in water, ammonia excreted by fish decreases and levels of ammonia in blood and tissue increase. The result is an elevation in blood pH and adverse effects on enzyme-catalyzed reactions and membrane stability. Ammonia also increases oxygen consumption by tissues, damages gills, and reduces the ability of blood to transport oxygen. Histological changes occur in the kidneys, speen, thyroid tissues and blood exposed to sublethal concentrations of ammonia. Exposure to sublethal concentrations of ammonia probably increases susceptibility of fish to diseases (Boyd 1982).

Several methods were used to prevent or reduce dissolved oxygen problems. These included:

1) Stopping or reducing fertilizer application depending on the severity of the problem.
2) Aeration either with an aerator or outboard motor.
3) Adding fresh water.

Richard and Hynes (1986) suggest two other methods to prevent DO problems. These include:

1) Using potassium permanganate (at 2-6 mg/L) to increase oxidation of organic material.
2) Mechanical removal of macrophytes.

4.3.2 Predation

Pike and burbot juveniles were inadvertently introduced to Meadow Lake and Jackfish Ponds. Stomach analyses of burbot sampled from these ponds indicated a purely insect diet. Pike fingerling densities (no/ha) were 257, 41 and 23 for Meadow Lake Cell 1, Cell 2 and Jackfish Pond, respectively.

Meadow Lake Cell 1 had half the walleye fry stocking rate (25 000/ha) of Cell 2 (50 000/ha) and had over 6X the pike density of Cell 2 at harvest time. Three weeks after walleye were stocked, pike predation was found to be minimal as the majority of them were feeding on insect forage. Obtaining sufficient numbers of walleye in Cell 1 for analysis became difficult by week 4. No walleye could be captured in weeks 5 and 6. Stomach analysis of pike trapped at this time indicated heavier predation on walleye. No significant pike predation on walleye was detected in Cell 2. The walleye density of Cell 1 and Cell 2 at harvest was 45/ha and 27 000/ha respectively.

In Jackfish Pond a walleye stocking rate of 15 400 fry/ha was used. The pike fingerling density in Jackfish Pond at harvest was more than 11X lower than that of Meadow Lake Cell 1 at harvest. Stomach analyses of pike captured from Jackfish Pond during harvest showed 2% were feeding on walleye. However, the majority of pike were feeding on either spottail shiners (23%) or brook stickleback (15%) introduced by pumping, or, had empty stomachs (60%). The walleye fingerling density at harvest was an estimated 3 814/ha. Although yellow perch fingerlings were present at an estimated density of 410/ha, none were detected in pike stomach contents. No walleye were found in perch stomach contents.

Several studies indicate a divergence of size associated with a lack of food is conducive to cannibalism (Stickney 1986, Loadman *et al.* 1986, Hokanson and Lien 1986, Krise and Meade 1986). Instances of cannibalism in Codette Pond can be attributed to a divergence in size (Fig. 14) and low forage levels at the time of harvest. Overall fingerling production of Codette Pond was likely not adversely affected as cannibalism was limited to a small percentage of the fingerling population over a short period. Cannibalism was not detected in the other rearing ponds.

Bird predation was observed during pond drawdown at Meadow Lake and Jackfish Ponds. Common terns accounted for the bulk of the fingerling loss through bird predation, but Franklin's gulls were also observed feeding on walleye fingerlings. There was no quantification of numbers taken but two separate observations at Meadow Lake showed 6 terns made 11 dives/2 min. and 8 terns made

30 dives/min. Schramm *et al.* (1987) has quantified bird consumption rates. Common terns were found to require 38-55 g/day of small fish and gulls require 58-168 g/day depending on species.

Jackfish Pond contained a large population of tiger salamanders *(Necturus maculosus)*. Several pond failures in Minnesota have been associated with large populations of mud puppies (Smith and Moyle 1945), a closely related species. No walleye fingerlings were found in the stomachs of salamanders sampled from Jackfish Pond.

Dytiscid and dragonfly larvae are known to be predaceous on small fish (Richard and Hynes 1986). Both groups were found in Meadow Lake and Jackfish Ponds, in small numbers. It is unlikely predatory insects significantly influenced walleye production this year.

4.3.3 Post Stocking Mortality of Harvested Fingerlings

Warm, muddy water in the Meadow Lake capture ponds combined with seining was stressful for the walleye fingerlings; as a result, post stocking mortality could be high. The fingerlings were hauled in 17°C water with both oxygen and agitation to reduce mortality while in transit. Richard and Hynes (1986) recommend hauling fingerlings at 19-21°C.

5. SUMMARY/CONCLUSIONS

Results of this year's operation indicate that pond fertilization was effective in stimulating zooplankton production which in turn bolstered walleye fingerling production. Overall

usable zooplankton production was barely adequate for walleye production indicating fertilization rates were too low to sustain higher densities. The effectiveness of pond fertilization is variable, depending on pond conditions and natural fluctuations in zooplankton densities. The high primary production observed in Codette Pond is attributed to the use of 11-51-0 granular ammonium phosphate. Fertilization contributed to the production of 27 000 fingerlings/ha (averaging 9100/ha) this year. The average from other years was about 6 000/ha, however stocking rates were lower.

Growth of fingerlings in the rearing ponds was similar to that observed in fertilized ponds in other years. Stocking density had little effect on fingerling growth over the period of pond culture (45 - 60 days). Average survival of walleye from fry to fingerling stage was 29.5% compared to 8.7% in 1986.

Sources of mortality include low dissolved oxygen levels associated with toxic ammonia levels in alkaline conditions, pike predation, cannibalism, bird predation and stress induced by harvesting methods (Meadow Lake Pond). The effects of finclipping were found to be negligible (Codette Pond).

6. RECOMMENDATIONS

Appendix 6 summarizes the recommendations for the 1988 rearing pond operations: Codette, Jackfish, Meadow Lake 1, Meadow Lake 2, Glaslyn, Shore.

6.1 POND FERTILIZATION

The use of alfalfa hay bales, alfalfa pellets and superphosphate (11-51-0) as fertilizer should continue. The total amount should remain the same, but frequency of application should be increased to foster better phytoplankton and zooplankton production.

Codette and Meadow Lake Ponds should receive alfalfa bales at a rate of 15 bales/ha. Alfalfa pellets should be applied at a rate of 400 kg/ha 10-14 days before stocking. Three days before stocking fry, another 250 kg/ha alfalfa pellets should be applied. Three additional applications of alfalfa pellets (250 kg/ha application) should follow within a month of stocking. In Codette Pond, an initial application of superphosphate at 10 kg/ha and a further three applications at 5 kg/ha should be applied in conjunction with the alfalfa pellets, beginning three days before stocking.

Jackfish Pond should receive alfalfa pellets (400 kg/ha) one week before stocking and 3 additional applications (250 kg/ha application) within a month after stocking.

Glaslyn and Shore Ponds should be operated as natural ponds, with no applications of fertilizer. Shore Pond should operate only if it fills sufficiently by spring runoff.

6.2 STOCKING FRY

Since better results were achieved in the ponds stocked at higher rates in 1987, it is recommended that higher rates be attempted in some ponds in 1988.

The suggested stocking rate for Meadow Lake Pond 2 is 75 000 fry/ha, for Codette and Meadow Lake Pond 1 is 50 000 fry/ha, for Jackfish and Glaslyn Ponds is 25 000 fry/ha and for Shore Pond is 12 500 fry/ha (if it fills naturally). Enumeration of fry by volumetric measurement of eyed eggs (von Bayer method) should again be conducted.

6.3 AERATION

Low dissolved oxygen concentrations have been identified as an important source of fingerling mortality during 1986 and 1987 pond operations. Since increased fertilization is recommended, the danger of summerkill will be more prevalent.

Aeration of Codette and Meadow Lake Ponds is recommended for the 1988 operations. This will help maintain dissolved oxygen levels, provide an oxygen refuge for the fingerlings and speed nutrient cycling.

6.4 POND ALTERATION AND DESIGN

Significant emergent growth and shallow areas are suspect in reducing Jackfish Pond fingerling production. Vegetation removal and basin alteration (deepening to a mean depth of 2.0 m and reducing the surface area to 10 ha or less) are two possible means of alleviating the problem. Removal of vegetation should be attempted

first as it is the less costly method. Basin alteration of Glaslyn Pond could also be considered to reduce the amount of shallow area and allow efficient aeration.

Multi-celled ponds facilitate simultaneous operational experiments and can buffer pond failure; overall pond production from the pond complex may be successful despite the failure of one cell, reducing financial loss. Each cell of a pond is more easily managed (innoculating zooplankton applying fertilizer draining or refilling, harvesting) than a single large pond. Multi-celled ponds should be considered for excavated rearing ponds built in the future.

6.5 MONITORING PROCEDURES

Water temperature, dissolved oxygen, pH, ammonia, chlorophyll *a* and zooplankton (kinds and size distribution) should be monitored prior to pond fertilization and weekly thereafter until 6 weeks after stocking fry.

Weekly sampling of walleye by seine or trap should begin 2 weeks after stocking. A minimum of 50 fingerlings/sample should be collected for determination of growth rate and stomach content.

Water level, submerged macrophytes and benthos should be noted at each pond visit.

6.6 FINGERLING HARVEST PROCEDURES

Mark/recapture methods of population estimates are the preferred procedure to minimize stress on the entire walleye fingerling population - only a subpopulation of the entire population is subjected to the stress of handling.

Meadow Lake and Glaslyn Ponds are located some distance from the lake receiving the fingerlings, and require handling of all fingerlings. Every effort should be made to reduce mortality caused by handling and seining. Bottled oxygen should always be kept on standby for emergency aeration and the use of anesthetics should be considered to reduce the fishes' metabolic activity without reducing temperature. The use of MS 222 is effective, but common salt (sodium chloride) has been effectively used by Ontario culturalists and fish farmers. If sodium chloride is used, a 1% solution (with clean water) should be prepared before fish are added to the water.

Water currents are effective in attracting the fingerlings to trapnets (for mark/recapture estimates) or control structures (Liaw 1987, Campbell and Rowes 1980). Harvesting is recommended at 55-60 days after stocking (mid-July).

6.7 POND WATER LEVELS

Pond water levels should be maintained at or near FSL throughout the growing period. Addition of water can significantly dilute zooplankton concentrations; in the 1987 operation of Codette Pond the usable zooplankton concentration dropped from 94 to 46 organisms/L by the addition of 30 cm of water to bring the pond to FSL. This is 15% of the water volume at FSL.

Meadow Lake Pond should be filled in late fall to prevent introduction of pike. Care should be taken to screen the water source, although any fish entering the pond would probably winterkill.

Emergent vegetation should be mechanically removed from Jackfish Pond before refilling in the spring. The seepage problem in Codette Pond leaves spring pumping as the only option.

Ponds should be filled to FSL to accommodate the fertilization and stocking schedule.

Until access is improved to Shore Pond, it should be operated as a natural pond only when it fills by spring runoff.

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8. APPENDICES

Appendix 1. Water analyses results - Meadow Lake Rearing Pond - 1987; units in ppm unless otherwise indicated.

Location	Meadow Lake Cell 1		Meadow Lake Cell 2	
Date Sampled	7 July 87	14 July 87	7 July 87	14 July 87
Parameter				
pH	8.50	8.10	8.20	8.70
Calcium	86.00	59.00	75.00	85.00
Iron	0.80	7.50	0.30	7.30
Magnesium	53.00	34.00	33.00	43.00
Manganese	0.01	<0.01	0.02	<0.01
Potassium	5.00	6.00	5.00	6.00
Sodium	39.00	28.00	23.00	32.00
Bicarbonate	295.00	251.00	317.00	315.00
Carbonate	7.00	-	-	-
Chloride	30.00	10.00	8.00	12.00
Sulphate	222.00	118.00	95.00	198.00
Phosphorus - total	0.11	1.25	0.12	1.25
Phosphorus - ortho	0.04	<0.25	0.07	<0.25
Nitrogen - Kjeldahl	2.30	7.50	2.60	5.00
Nitrogen - ammonia	0.08	1.25	0.78	1.25
Nitrogen - nitrate	<0.03	0.14	0.03	0.03
Dissolved organic carbon	27.00	24.00	24.00	24.00
Total alkalinity as $CaCO_3$	254.00	206.00	260.00	258.00
Phenol alkalinity as $CaCO_3$	6.00	-	-	-
Total hardness as $CaCO_3$	436.00	288.00	324.00	388.00
Suspended solids - total	34.00	298.00	7.00	258.00
Suspended solids - volatile	7.00	74.00	3.00	52.00
Conductivity (µS/cm)	880.00	600.00	640.00	816.00
Total dissolved solids	738.00	506.00	556.00	691.00
BOD (5 days)	2.50	13.00	2.00	6.00

NB/rearing pond samples taken on 14 July 1987 were muddy.

Appendix 2. Water analyses results - Meadow Lake Rearing Pond drainage canal - 1987; units in ppm unless otherwise indicated.

Location	Drainage Canal Joining Rearing Pond Cells to Meadow River	
Date Sampled	Site 1	Site 2
Parameter	7 July 87	7 July 87
pH	8.30	8.50
Calcium	67.00	80.00
Iron	0.30	1.00
Magnesium	30.00	50.00
Manganese	0.01	0.01
Potassium	6.00	5.00
Sodium	23.00	36.00
Bicarbonate	317.00	285.00
Carbonate	-	7.00
Chloride	4.00	16.00
Sulphate	73.00	194.00
Phosphorus - total	0.15	0.10
Phosphorus - ortho	0.09	0.05
Nitrogen - Kjeldahl	2.80	2.10
Nitrogen - ammonia	0.87	0.05
Nitrogen - nitrate	0.03	<0.03
Dissolved organic carbon	24.00	25.00
Total alkalinity as $CaCO_3$	260.00	246.00
Phenol alkalinity as $CaCO_3$	-	6.00
Total hardness as $CaCO_3$	292.00	404.00
Suspended solids - total	5.00	37.00
Suspended solids - volatile	3.00	8.00
Conductivity (µS/cm)	610.00	820.00
Total dissolved solids	520.00	673.00
BOD (5 days)	2.80	2.30

Appendix 3. Water analyses results - Meadow River - 1987; units in ppm unless otherwise indicated.

Location	Meadow River*		Meadow River**	
Date Sampled	7 July 87	14 July 87	7 July 87	14 July 87
Parameter				
pH	8.50	8.50	8.60	7.80
Calcium	59.00	38.00	45.00	38.00
Iron	1.20	0.10	0.70	1.40
Magnesium	32.00	22.00	20.00	21.00
Manganese	<0.01	<0.01	0.01	<0.01
Potassium	5.00	5.00	5.00	6.00
Sodium	21.00	15.00	14.00	15.00
Bicarbonate	268.00	244.00	237.00	246.00
Carbonate	-	10.00	7.00	-
Chloride	6.00	<2.00	<2.00	2.00
Sulphate	94.00	14.00	14.00	16.00
Phosphorus - total	0.10	0.14	0.14	0.14
Phosphorus - ortho	0.02	0.01	0.06	0.01
Nitrogen - Kjeldahl	1.50	1.80	1.80	1.80
Nitrogen - ammonia	0.09	0.05	0.08	0.08
Nitrogen - nitrate	<0.03	<0.03	<0.03	<0.03
Dissolved organic carbon	22.00	20.00	21.00	21.00
Total alkalinity as $CaCO_3$	228.00	200.00	206.00	202.00
Phenol alkalinity as $CaCO_3$	4.00	8.00	6.00	
Total hardness as $CaCo_3$	280.00	188.00	196.00	184.00
Suspended solids - total	37.00	25.00	49.00	
Suspended solids - volatile	10.00	16.00	20.00	
Conductivity (µS/cm)	550.00	369.00	380.00	378.00
Total dissolved solids	490.00	348.00	342.00	344.00
BOD (5 days)	2.90	2.00	3.40	***

* (upstream of drainage canal)
** (at town water treatment plant intake)
***lab accident

Appendix 4. Results of bacteriological counts (MF method/100 mL) from the Meadow Lake Rearing Pond and associated water bodies.

Location	Meadow Lake Cell 1		Meadow Lake Cell 2	
Date Sampled	7 July 87	14 July 87	7 July 87	14 July 87
Parameter	No/dL		No/dL	
Total coliforms	600	2300	600	2300
Fecal coliforms	<10	2300	<10	430
Fecal streptococci	<10	2700	<10	200

	Meadow River*		Meadow River**	
	7 July 87	14 July 87	7 July 87	14 July 87
Total coliforms	400	<30	30	1500
Fecal coliforms	10	<30	130	30
Fecal streptococci	40	<100	30	<100

	Drainage Canal Site 1	Drainage Canal Site 2
	7 July 87	7 July 87
Total coliforms	900	1600
Fecal coliforms	600	460
Fecal streptococci	6	50

* (upstream of drainage canal)
** (at town water treatment plant intake)

Appendix 5. Fork length, total length and weight of walleye from the rearing ponds. Sample size is in brackets.

Pond	Date Sampled	Days In Pond	Fork Length (mm) X ± SD	Total Length (mm) X ± SD	Weight (g)	
Codette	9 June 87	15	15.9 ± 0.69	16.9 ± 0.69	0.047	(50)
	15	21	22.6 ± 1.98	24.4 ± 2.02	0.164	(50)
	22	28	33.7 ± 2.10	36.2 ± 2.12	0.469	(50)
	25	31	38.2 ± 3.34	40.8 ± 3.45	0.674	(50)
	1 July 87	37	46.3 ± 3.33	49.4 ± 3.46	1.085	(50)
	21	57	53.4 ± 4.83	57.7 ± 5.19	1.487	(50)
	28	64	62.5 ± 7.60	66.9 ± 7.99	2.393	(50)
Jackfish	10 June 87	16	15.7 ± 0.58	16.7 ± 0.59	0.053	(50)
	16	22	21.7 ± 1.43	23.3 ± 1.51	0.143	(50)
	23	29	31.8 ± 2.04	33.9 ± 2.01	0.404	(50)
	29	35	39.0 ± 2.98	41.9 ± 3.05	0.692	(50)
	10 July 87	46	51.6 ± 3.14	55.1 ± 3.32	1.503	(75)
	13	49	53.6 ± 3.35	57.7 ± 3.38	1.717	(63)
Meadow Lake (Cell 1)	11 June 87	15	16.0 ± 0.60	17.0 ± 0.62	0.056	(50)
	17	21	22.9 ± 1.21	24.5 ± 1.21	0.170	(50)
	23	27	29.2 ± 2.22	31.2 ± 2.25	0.340	(50)
	10 July 87	44	47.5 ± 2.33	50.6 ± 2.44	1.141	(41)
(Cell 2)	11 June 87	15	15.7 ± 0.73	16.7 ± 0.75	0.057	(43)
	17	21	22.9 ± 1.15	24.5 ± 1.13	0.185	(50)
	23	27	31.8 ± 2.45	33.9 ± 2.48	0.443	(50)
	29	33	39.7 ± 2.56	42.7 ± 2.52	0.774	(50)
	10 July 87	44	50.9 ± 3.98	54.3 ± 4.19	1.479	(24)

Appendix 6. Rearing Pond Operations, 1988 Recommendations.

Ponds	Area (ha)	Number Fry/ha	Total No. Fry/ha	No. of Alfalfa Bales	Alfalfa Pellets kg/ha	Alfalfa Pellets No. Bags	Superphosphate kg/ha	Superphosphate Total
Codette	10.0	50 000	500 000	150	1400	560	25	250
Jackfish	13.0	30 000	390 000	-	1150	598	-	-
Meadow Lake #1	6.2	50 000	310 000	95	1400	347	25	155
Meadow Lake #2	3.6	50 000	180 000	55	1400	201	25	90
Glaslyn	4.0	30 000	120 000	-	1000	160	-	-
Shore	19.0	-	-	-	-	-	-	-
			1 500 000			1866		495